ISSN 0377–9335

Vol. 33 December 2008 No. 4

CONTENTS

SHORT COMMUNICATIONS

Centre for Arthropod Bioresources and Biotechnology (CABB),
University of Kerala, Kariavattom, Trivandrum, India 695 581

ENTOMON

ENTOMON is a quarterly journal of the Association for Advancement of Entomology issued in March, June, September and December, devoted to publication of research work on various aspects of insects and other arthropods.

Address MS and all editorial correspondence to Managing Editor, ENTOMON, Centre for Arthropod Bioresources and Biotechnology (CABB), University of Kerala, Kariavattom, Trivandrum 695581, India.

SUBSCRIPTION RATES

Annual subscription for Institutions: Rs. 2000.00 (in India); US$ 250 (Air Mail)
Annual subscription for individuals: Rs. 300.00 (in India); US$ 100 (Air Mail)

1. All remittance to the Journal or Association should be sent to the Secretary-Treasurer of the Association by Bank Draft only, A/c payee in favour of the Association for Advancement of Entomology, payable at Kariavattom.
2. Requests for replacement copies of ENTOMON in lieu of numbers lost in transit, should reach the Secretary-Treasurer not later than three months after the date of publication of the number.

ENTOMON is covered in the following abstracting/indexing journals: *Chemical Abstracts, Review of Applied Entomology, Science Citation Index* and *Current Contents/Agriculture, Biology* and *Environmental Sciences, Biological Abstracts, Entomology Abstracts* and other relevant abstracts, *Referativny Zhurnal* and *Current Advance in Biological Sciences* and *New Entomological Taxa*.

ENTOMON **33(4)**: 227–232 (2008)
Article No. ent.33401

Relative toxicity of two organophosphorous insecticides and polymorphic resistance in *Rhynocoris marginatus* (Fabricius) (Hemiptera: Reduviidae)

Dunston P. Ambrose*, Annie D. Ambrose†, N. Jeyanthi and S. P. M. Maran

Entomology Research Unit, St. Xavier's College (Autonomous), Palayankottai 627 002, Tamil Nadu, India
Email: eruxavier@gmail.com

ABSTRACT: *Rhynocoris marginatus* (Fabricius) is a polymorphic reduviid predator on insect pests. It exists in three different morphs; (1) with black connexivum (niger); (2) with red connexivum (sanguineous) and with black and red banded connexivum (nigrosanguineous). Relative toxicity of two organophosphates viz., monocrotophos and methyl parathion to *R. marginatus* was assessed through bioassay and the latter was found to be comparatively more toxic. *R. marginatus* resisted organophosphates by detoxification through carboxyl esterase activity. Thus, the niger morph with higher and sanguineous morph with lower carboxyl esterase activity were the most resistant and sensitive morphs, respectively. Above findings are useful to screen the insecticides and predators for integrated pest management programmes.

KEYWORDS: *Rhynocoris marginatus*, relative toxicity, organophosphates, polymorphic adaptive resistance, carboxyl esterase

INTRODUCTION

Many reduviids are essential predators on insect pests of crops, playing a significant role in keeping pest populations under check (Schaefer, 1988; Ambrose, 1999, 2000, 2003). *Rhynocoris marginatus* (Fabricius) is an excellent reduviid predator predominantly found in agroecosystems, scrub jungles and semiarid zones bordering agroecosystems in India. It exists in three different morphs: (1) with black connexivum (niger); (2) with red connexivum (sanguineous); and (3) with black and red banded

*Corresponding author
†Department of Zoology, Rani Anna Govt. Arts College for Women, Tirunelveli 627 008, India

connexivum (nigrosanguineous) (Ambrose, 1999). All the three morphs inhabit agroecosystems and the insecticides used to manage the insect pests affect these non-target biocontrol agents. The present study was undertaken to find out the relative toxicity of two organophosphorous insecticides viz., monocrotophos and methyl parathion to *R. marginatus* and whether there is any polymorphic adaptive resistance to these insecticides among its morphs. Such knowledge is essential to choose the biocontrol agent friendly insecticide and also to conserve and augment the better-adapted morph for subsequent utilization in insect pest management programmes. Though information is available on alary polymorphism in *Coranus subapterus* DeGeer (Wallace, 1953), *Rhynocoris* species (Louis, 1974) and *R. marginatus* (Ambrose and Livingstone, 1987, 1988) and polymorphic resistance to insecticides (George and Ambrose, 1996, 2001), the underlying mechanism for such polymorphic adaptive resistance is unknown. Hence, the present study envisaged the assessment of relative toxicity and the mechanisms that govern the polymorphic adaptive resistance, if any.

MATERIALS AND METHODS

Adults and nymphs of the three morphs of *R. marginatus* were collected from Thiyagarajanagar semiarid zone bordering agroecosystems in Tirunelveli District, Tamil Nadu. The three morphs were separately reared in plastic rearing containers (10 cm × 4 cm) on head crushed larvae of flour moth *Corcyra cephalonica* (Stainton) in the laboratory (Ambrose, 1999). Adults obtained from the cultures kept in the laboratory were used for the experiments.

For assessing the relative toxicity of monocrotophos and methyl parathion adults of *R. marginatus* were individually exposed to cotton leaves cut in circular bits (4 cm dia) and sprayed with the insecticide preparation, dried and taken in rearing containers. Each insecticide was applied in five graded concentrations and in each concentration 30 insects were exposed in 30 rearing containers with treated leaves. As control, 30 insects were similarly exposed to cotton leaves sprayed with water alone. Treated insects were exposed continuously for a period of 96 h and the mortality was recorded at 24, 48, 72 and 96 h following insecticide treatment. Moribund insects were treated as dead. The mortality data were corrected by Abbott's formula (1925) and the same were subjected to probit analysis (Finney, 1971).

Since carboxyl esterase enzymes are involving in the detoxification of organophosphates in insects, carboxyl esterase activity in the haemolymph of three polymorphic forms of *R. marginatus* viz., niger, sanguineous and nigrosanguineous was assessed to understand the differential polymorphic resistance. The predators were exposed to two sublethal concentrations each of the two insecticides for varying durations. Haemolymph was collected from the severed fore tarsi or antennae of the morphs in each replication in pre-cooled eppendorf tubes containing sodium citrate as anticoagulant. Samples were first tested for the presence of esterase (Dhiman and Kumar, 1989) and then carboxyl esterase activity levels were estimated following the methods of van Asperen and Oppenoorth (1959), and protein concentration was measured following the method of Lowry *et al.* (1951) using bovine serum albumin (BSA) as standard.

TABLE 1. Toxicity of monocrotophos to *R. marginatus*

Exposure duration (h)	X^2	Regression equation $Y =$	'r'	P	LC_{50} (%)	Fiducial limits	Variance	Toxicity level
24	0.03	$2.814x - 0.68$	0.970	< 0.01	0.104	0.081–0.1.34	0.0031	1.000
48	0.12	$2.521x - 0.31$	0.957	< 0.01	0.072	0.060–0.088	0.0018	1.444
72	0.60	$2.979x - 0.26$	0.966	< 0.01	0.058	0.049–0.069	0.0015	1.793
96	1.48	$3.960x - 1.67$	0.940	< 0.05	0.048	0.041–0.057	0.0014	2.167

$n = 30$; $df = 3$

TABLE 2. Toxicity of methyl parathion to *R. marginatus*

Exposure duration (h)	X^2	Regression equation $Y =$	'r'	P	LC_{50} (%)	Fiducial limits	Variance	Toxicity level
24	0.36	$2.442x - 1.36$	0.991	< 0.001	0.031	0.025–0.038	0.0020	1.000
48	7.36	$2.910x - 1.22$	0.872	< 0.05	0.020	0.016–0.025	0.0025	1.550
72	4.11	$3.157x - 1.30$	0.899	< 0.05	0.015	0.011–0.020	0.0037	2.067
96	1.51	$2.958x - 1.90$	0.948	< 0.05	0.011	0.007–0.016	0.0059	2.818

$n = 30$; $df = 3$

RESULTS

Relative toxicity

The LC_{50}, fiducial limits and regression equations for monocrotophos and methyl parathion exposure to *R. marginatus* at 24, 48, 72 and 96 h durations were calculated (Tables 1 & 2). The toxicity levels of methyl parathion on *R. marginatus* at all durations of exposure were comparatively higher than those of monocrotophos. LC_{50} values were 1.0, 1.55, 2.07 and 2.82 at 24, 48, 72 and 96 h exposures for methyl parathion whereas they were 1.0, 1.4, 1.8 and 2.17 at 24, 48, 72 and 96 h exposure for monocrotophos (Tables 1 & 2).

Polymorphic adaptations

The carboxyl esterase activity to sublethal concentrations of monocrotophos and methyl parathion in different morphs of *R. marginatus* are given in Tables 3 and 4. All treatments caused an increase in carboxyl esterase activity. Protein carboxyl esterase activity increased in all the three morphs as the concentrations of insecticides and durations of exposure of insecticides increased. The carboxyl esterase activity to detoxify the more toxic methyl parathion was relatively higher than that to the less toxic monocrotophos in all the three morphs of *R. marginatus* irrespective of the sublethal concentrations and durations of exposure (Tables 3 & 4).

Though all the three morphs exhibited carboxyl esterase activity to detoxicify the organophosphates the niger morph exhibited the highest carboxyl esterase activity

TABLE 3. Carboxyl esterase activity to sublethal concentrations (1/10 and 1/5 of 96 h LC_{50}) of monocrotophos in three morphs of *R. marginatus*

Sublethal concentrations of monocrotophos	Exposure duration (days)	Morphs		
		Niger	Sanguineous	Nigrosanguineous
1/10	1	23.46aA	15.56bA	20.29aA
	5	35.32aB	19.22bB	28.89cB
	10	46.39aC	29.84bC	38.33cC
1/5	0	20.62aA	12.99bA	18.49aA
	1	36.74aB	23.46bB	32.23cB
	5	51.44aC	28.30bC	45.62cC
	10	80.03aD	38.51bD	55.06cD

$n = 10$
Means carrying same alphabets (small letters) in a row are not significantly different at $P < 0.001$ by ANOVA
Means carrying same alphabets (capital letters) in a column are not significantly different at $P < 0.001$ by ANOVA

TABLE 4. Carboxyl esterase activity to sublethal concentrations (1/10 and 1/5 of 96 h LC_{50}) of methyl parathion in three morphs of *R. marginatus*

Sublethal concentrations of monocrotophos	Exposure duration (days)	Morphs		
		Niger	Sanguineous	Nigrosanguineous
1/10	1	29.46aA	17.21bA	27.20aA
	5	45.09aB	28.23bB	36.34cB
	10	66.28aC	36.07bC	50.07cC
1/5	0	20.62aA	12.99bA	18.49aA
	1	38.09aB	28.19bB	36.84aB
	5	51.62aC	31.19bB	45.73cC
	10	80.62aD	40.94Bc	64.64cD

$n = 10$
Means carrying same alphabets (small letters) in a row are not significantly different at $P < 0.001$ by ANOVA
Means carrying same alphabets (capital letters) in a column are not significantly different at $P < 0.001$ by ANOVA

followed by nigrosanguineous morph. For instance, niger morphs showed 20.62 $\pm$ 0.28 μm/min/mg protein carboxylesterase activity whereas nigrosanguineous and sanguineous morphs exhibited 18.49 $\pm$ 0.47 and 12.99 $\pm$ 0.19 μm/min/mg protein carboxyl esterase activity (Tables 3 & 4), suggesting that the niger morph is the most resistant and the sanguineous morph the most sensitive to the tested organophosphates.

ENTOMON 33(4): 233–236 (2008)
Article No. ent.33402

Effect of soil texture on infectivity of entomopathogenic nematode, *Steinernema glaseri* to whitegrub, *Holotrichia consaguinea* Blanch

Sardar Singh Bareth and Ashok Bhatnagar

Department of Entomology, Agricultural Research Station, Rajasthan Agricultural University, Durgapura, Jaipur, Rajasthan 302 018, India
Email: ab_171956@yahoo.in

ABSTRACT: The effect of three different soil textures i.e. sandy, loamy sand and sandy loam, on the infectivity of entomopathogenic nematode, *Steinernema glaseri* was tested against first instar grubs of *Holotrichia consanguinea* in the laboratory. Infectivity of *S. glaseri* to Ist instar grubs of *H. consanguinea* occurred earlier in sandy soil, followed by loamy sand and late in sandy loam soil. The lethal infection rate index (LIRI) was 146.03, 107.33 and 100 in sand, loamy sand and sandy loam soils, respectively.

KEYWORDS: soil texture, entomopathogenic nematode, whitegrub

INTRODUCTION

Holotrichia consanguinea Blanch is the most serious rainy season pest of light sandy soils in the northern parts of India. It is polyphagus and is a major constraint in kharif cultivation in many parts of Rajasthan, where lighter soils are common (Yadava, 1981). Insecticides are effective against the pest. But it causes pollution and may impair the soil fauna, thereby reducing soil fertility in the long term. Hence more eco-friendly and less expensive alternative technologies are being sought at present. Biocontrol agents are undoubtedly the major component of the newer technology under investigation and insect parasitic nematodes have emerged as a promising group. *Steinernema glaseri* has been extensively tested against soil pests (Poinar, 1986, Walter, 1968, Villani and Wright, 1988). Information is needed on the interaction of soil environment and nematode parasite to assess the possible efficacy. The interaction between different soil types prevalent in Rajasthan and nematode pathogenicity to the host, *H. consanguinea* was assessed in the laboratory.

DISCUSSION

The differential insecticidal resistance exhibited by the morphs of *R. marginatus* revealed its intraspecific adaptive morphic value. Mayr (1969) defined polymorphism as variability within a population. Breeding experiments between morphs of a particular ecotype by Ambrose and Livingstone (1988) revealed that such intraspecific variations were not strictly genetic. They further reported that the level of population of different morphs both in the field and in the laboratory suggested that the segregation phenomenon did not occur in the Mendelian fashion. Such random occurrence of morphs without any relation to environmental or genetic basis was termed as a non-mutational and non-adaptive trend in evolution (Simpson, 1969). However, the adaptive significance of a particular morph in a given ecotype cannot be ruled out as evidenced by niger with its higher insecticidal resistance which was reported by Ambrose and Livingstone (1988) with reference to its biological attributes and by George and Ambrose (1996, 2001) with reference to its insecticidal resistance based on LC_{50} values. The present study not only established the relative toxicity of the two insecticides based on the LC_{50} values but also revealed the variation in protein carboxyl esterase activity. The most resistant niger morph could prove better in biological control programmes.

ACKNOWLEDGEMENTS

We are grateful to the authorities of St. Xavier's College for facilities. One of us (DPA) gratefully acknowledges the financial assistance received from Department of Science and Technology, Govt. of India (Ref. No. SR/SO/AS/14-2002).

REFERENCES

Abbott, W. S. (1925) A method for computing the effectiveness of an insecticide. *Journal of Economic Entomology* 18: 265–267.

Ambrose, D. P. (1995) Reduviids as predators: their role in biological control. In: *Biological Control of Social Forests and Plantation crops Insects*. Ananthakrishnan, T. N. (Ed). Oxford & IBH Publishing Company Private Limited, New Delhi, India, 153–170.

Ambrose, D. P. (1999) *Assassin Bugs*, Science Publishers: New Hampshire, U.S.A. and Oxford and IBH Publishing Company Private Limited, New Delhi, India.

Ambrose, D. P. (2000) Assassin Bugs (Reduviidae excluding Triatominae). In: *Heteroptera of Economic Importance*, Schaefer, Carl W. and Panizzi, A. R. (Eds). CRC Press, Florida, U.S.A, 695–712.

Ambrose, D. P. (2003) Biocontrol potential of assassin bugs (Hemiptera: Reduviidae). *Journal of Experimental Zoology, India* 6(1): 1–44.

Ambrose, D. P. and Livingstone, D. (1987) Biology of *Acanthaspis siva* Distant, a polymorphic assassin bug (Insecta: Heteroptera: Reduviidae). *Mitterand Zoological Museum, Berlin*, 321–330.

Ambrose, D. P. and Livingstone, D. (1988) Polymorphism of *Rhynocoris marginatus* (Fabricius) (Insecta: Heteroptera: Reduviidae). *Mitterand Zoological Museum, Berlin* 64: 343–348.

Dhiman, S. C. and Kumar, R. (1989) Studies on enzymes in the salivary glands of *Leptocoris augur* (Fabr.) (Heteroptera: Rhopalidae). *Nutritional Ecology of Insects and Environment* 116–120.

Finney, D. J. (1971) *Probit Analysis*, 3rd edn, Cambridge University Press, Cambridge, 150–158.

George, P. J. E. and Ambrose, D. P. (1996) Adaptive polymorphism in *Rhynocoris marginatus* (Fabricius) to two insecticides, a non-target biocontrol agent (Insecta: Heteroptera: Reduviidae). In: *Biological and Cultural Control of Insect Pests, an Indian Scenario*, Ambrose, D. P. (Ed). Adeline Publishers, Tirunelveli, India, 120–124.

George, P. J. E. and Ambrose, D. P. (2001) Polymorphic adaptive insecticidal resistance in *Rhynocoris marginatus* (Fabr.) (Het., Reduviidae) a non-target biocontrol agent. *Journal of Applied Entomology*, 207–209.

Louis, D. (1974) Biology of Reduviidae of cocoa forms in Ghana. *American Midland Naturalist* 9: 68–69.

Lowry, O. H., Rosebrough, N. H., Farr, A. L. and Randall, R. J. (1951) Protein measurement with the folin phenol reagent. *Journal of Biological Chemistry* 193: 265–275.

Mayr, E. (1969) *Principles of systematic Zoology*, Tata McGraw-Hill Publishing Company Limited, New Delhi, India.

Nagia, D. K., Kumar, S., Sharma, P. and Saini, M. L. (1990) Relative toxicity of some important insecticides to Bihar hairy caterpillar *Spilosoma obliqua* Walker (Arctidae, Lepidoptera). *Journal of Entomological Research* 14: 60–62.

Schaefer, C. W. (1988) Reduviidae (Hemiptera: Heteroptera) as agents of biological control. In: *Bicovas*, Ananthasubramanian, K. S., Venkatesan, P. and Sivaraman, S. (Eds). Loyola College, Madras, vol 1: 27–33.

Simpson, G. (1969) *The Meaning of Evolution*, Oxford and IBH Publishing Company Limited, New Delhi, India, p. 46.

van Asperen, K. and Oppenoorth, F. J. (1959) Organophosphate resistance and esterase activity in house flies. *Entomologia Experimentalia et Applicata* 2: 48–57.

Wallace, H. R. (1953) Notes on the biology of *Coranus subapterus* DeGeer (Hemiptera: Reduviidae). *Proceedings of Royal Entomological Society, London* 28: 100–110.

(Received 3 October 2008; accepted 30 November 2008)

MATERIALS AND METHODS

Soils of three different textures (sandy, loamy sand and sandy loam) which are common in the root grub infested tracts of Rajasthan were collected from farmer's fields near Jaipur. Sandy loam type of soil contained 78% sand, 8.58% silt and 13.38% clay; loamy sand type had 86% sand, 5.78% silt, 7.3% clay; and sand type had 89% sand, 5.9% silt and 4.9% clay. The soils were separately sterilized in autoclave and 100 g soil each was taken in a polyethylene container and in each container 3000 *S. glaseri* IJS and one seven day old, first instar grub of *H. consanguinea* was released. The grubs were surface disinfected before release. For each soil type 20 replications were set up and a similar set without IJs served as control.

The containers were incubated at 25 °C. The grub mortality was recorded daily upto ten days for computation of median lethal post exposure time (LT_{50}). The dead grubs were surface sterilized and placed over circular pieces of Whatman 40 filter paper placed over the convex bottom of screw capped bottles the edges of which was dipping in 0.1% formalin solution poured into the bottle. The nematode emergence from the cadavers confirmed nematode infection as the cause of mortality.

The mortalities in various treatments were adjusted for the mortality in control following the formula of Abbott (1925). The data were then subjected to probit analysis (Finney, 1971) for assessing the time required for causing 50% mortality and the lethal infection rate index (LIRI) was a computed following the method of Sun-Pei-Yun (1950).

RESULTS AND DISCUSSION

Data presented in Table 1 show that infectivity of *S. glaseri* to *H. consanguinea* grub was highest in sandy soil (LT_{50} 3.91) and it was followed by loamy sand (LT_{50} 5.32) and sandy loam soil (LT_{50} 5.71). As against the lethal infection rate index (LIRI) of 100 with sandy loam soil, the index of loamy sand and sandy soil was 107.33 and 146.03, respectively. Although the differences in the texture of soils used in the present studies was narrow a positive association with the sand content and a negative association with the clay content was evident in the infectivity of the pathogen.

Similar influence of soil type was reported on *Steinernematids* and *Heterorhabditids* infesting sheep blowfly (Molyneux and Bedding, 1984). Kung *et al.* (1990) observed that in lighter soils the nematodes survived for a longer period and hence parasitisation was more as compared to heavier soils. Higher pathogenicity in sandy soils compared to clayey types facilitated by easier movement and consequent success in host finding was reported by several authors earlier (Campbell and Gaugler, 1993; Grewal *et al.*, 1994; Barbercheck and Kaya, 1991; Georgis and Poinar, 1983a,b). Wallace (1971) also reported that the soil type, moisture and aeration inside the soil affect nematode movement and energy consumption. In good aeration conditions of sandy soils nematodes survive for a longer period and effectively parasitize the host (Croll and Mathews, 1977, Moyle and Kaya, 1981, Georgis and Gaugler, 1991).

TABLE 1. Effect of soil texture on infectivity of *S. glaseri* to first instar *H. consanguinea* grubs

Soil texture	Regression equation	LT_{50} (days)	LIRI
Sandy loam	$Y = 2.2584347 + 3.6249812X$	5.71	100
Loamy sand	$Y = 2.3461539 + 3.6523349X$	5.32	107.33
Sand	$Y = 1.4777341 + 5.9441514X$	3.91	146.03

X = days after inoculation; Y = Probit kill;
LT_{50} = median lethal time (days) post inoculation;
LIRI = lethal infection rate index; exposure arena, dia., 55 mm; ht., 65 mm;
Inoculation dose = 3000 IJs/grub/100 g soil/arena
The data as homogeneous at the 5% level of significance

From the results, it can be deduced that *S. glaseri* can infect *H. consanguinea* in soils ranging from sandy to sandy loam. The nematode takes more time to cause lethal infection in sandy loam and loamy sand soils compared to sandy soils and the defect can be compensated by increasing the dose of the pathogen applied.

REFERENCES

Abbott, W. S. (1925) A method for computing the effectiveness of insecticides. *J. Econ. Entomol* 18: 265–267.

Barbercheck, M. E. and Kaya, H. K. (1991) Effect of host condition and soil texture on host finding by entomogenous nematodes *Heterorhabditis bacteriophora* (Rhabditidae: Heterorhabditidae) and *Steinernema carpocapsae* (Rhabditidae: Steinernematidae). *Environ. Entomol* 29(2): 582–589.

Campbell, J. F. and Gaugler, R. (1993) Nictation behaviour and its ecological implications in the host search strategies of Entomopathogenic nematodes (Heterorhabditidae and Steinernematidae). *Behavior* 126: 155–169.

Croll, N. A. and Mathews, B. E. (1977) Survival of nematodes. In: *Biology of Nematodes*, Wiley, New York, 152–165.

Finney, D. J. (1971) *Probit Analysis*, 3rd edn, Cambridge University Press, Cambridge, p. 100.

F. E., Walter (1968) *Biological Control of the Japanese Beetle*, Tech. Bull. No. 1383, Agriculture Research Service, United States Department of Agriculture, p. 78.

Georgis, R. and Gaugler, R. (1991) Predictability in biological control using entomopathogenic nematodes. *J. Econ. Entomol.* 3: 713–720.

Georgis, R. and Poinar, G. O. Jr. (1983a) Effect of soil texture on the distribution and infectivity of *Neoplectana carpocapsae* (Nematoda: Steinernematidae). *J. Nematol.* 15(2): 308–311.

Georgis, R. and Poinar, G. O. Jr. (1983b) Effect of soil texture on the distribution and infectivity of *Neoplectana carpocapsae* (Nematoda: Steinernematidae). *J. Nematol* 15(3): 329–332.

Grewal, P. S., Lewis, E. E., Gaugler, R. and Campbell, J. F. (1994) Host finding behaviour as a anthophora predictor of foraging strategy in entomopathogenic nematodes. *Parasitology* 108: 207–215.

Kung, S. P., Gaugler, R. and Kaya, H. K. (1990) Soil type and entomopathogenic nematode persistence. *J. Invertebr. Pathol* 55(3): 401–406.

Molyneux, A. S. and Bedding, R. A. (1984) Influence of soil texture and moisture on the infectivity of *Heterorhabditis* sp. D1 and *Steinernema glaseri* for larvae of the sheep blow fly, *Lucilia cuprina*. *Nematologica* 30: 358–365.

Moyle, P. L. and Kaya, H. K. (1981) Dispersal and infectivity of the entomogenous nematode, *Neoaplectana carpocapsae* Weiser (Rhabditida: Steinernematidae) in sand. *J. Nematol* 13(3): 295–299.

Poinar, G. O. Jr. (1986) Entomogenous nematodes. In: *Biological plant and Health protection*, Franz, J. M. (Ed). Gustov Fischer Verlag, New York, 95–122.

Sun-Pei-Yun, (1950) Toxicity index. An improved method of comparing the relative toxicity of insecticides. *J. Econ. Entomol* 43: 45–53.

Villani, M. G. and Wright, R. J. (1988) Entomogenous nematodes as biological control agents of European chafer and Japanese beetle (Coleoptera: Scarabaeidae) larvae infesting turfgrass. *J. Econ. Ent.* 81(2): 484–487.

Wallace, H. R. (1971) Abiotic influences in the soil environment. In: *Parasitic Nematodes*, Zuckerman, B. M., Mai, W. F. and Rohde, R. A. (Eds). Academic Press, New York, 1: 257–280.

Yadava, C. P. S. (1981) *Integrated Control of Whitegrub*, Agric. Expteriment Station, Dept. of Ent. Univ. Udaipur Campus, Jobner.

(Received 5 May 2005; accepted 15 September 2008)

ENTOMON 33(4): 237–240 (2008)
Article No. ent.33403

Effect of combining different bollworm pheromone traps on same bamboo pole on moth catches in cotton fields

P. Jeyakumar[1], M. C. Jat[2], R. K. Tanwar[1], A. Dhandapani[1], D. Monga[2] and O. M. Bambawale[1]

[1]*National Centre for Integrated Pest Management, New Delhi 110 012, India*
Email: pjkumar_ento@rediffmail.com
[2]*Central Institute for Cotton Research, Regional Station, Sirsa 125 055, Haryana, India*

ABSTRACT: It is a standard practice to fix pheromone traps on separate bamboo poles for collecting the three bollworms, *Helicoverpa armigera*, *Earias* spp. and *Pectinophora gossypiella* in cotton fields for monitoring and decision making in IPM interventions. Possibility of combining traps was explored in 2004 and 2005 crop seasons in Rangri village, Sirsa, Haryana. Placing *P. gossypiella* trap with either *H. armigera* or *Earias* spp. traps resulted in reduction in the number of *H. armigera* or *Earias* spp. moth catches. This interference was negated when all the three traps were placed together. Placement of the traps of all the three species simultaneously on same bamboo pole at different heights is hence recommended. This practice saved around 49% of the monitoring costs.

KEYWORDS: pheromone traps, cotton, bollworms, trap integration

INTRODUCTION

Intensive studies on the sex pheromones of heliothine species, carried out during the last three decades (Dunkelblum and Kehat, 1989; Park *et al.*, 1994; Tamhankar *et al.*, 2003), resulted in a wide understanding of the communication system for mating in the noctuids. Pheromones are now being used as modern tools to monitor the pest population, which forms the basis for timing control measures (Rosaiah and Reddy, 1995). In India, pheromones have been proposed, evaluated and used as one of the key components of integrated management of insect pests.

In IPM programmes, pheromone traps are installed individually on bamboo poles at different heights, so as to avoid any possible interference of these semio-chemicals with each other. This incurs a lot of expenditure for bamboo sticks as well as manual labour for trapping the moths of American bollworm (ABW), *Helicoverpa armigera*;

TABLE 1. Moth catch efficiency of pheromone traps at various combinations

Pheromone trap	Year 2004	Year 2005	Pooled
Helicoverpa armigera moth catches/3 nights			
H alone	5.41[ab]	5.21[a]	5.31
H + E	5.73[a]	4.74[a]	5.24
H + P	3.95[b]	3.50[b]	3.72
H + E + P	4.78[ab]	4.92[a]	4.85
CD ($P = 0.05$)	1.68	0.81	NS
Earias spp. Moth catches/3 nights			
E alone	9.72	10.33[a]	10.30
E + H	8.60	8.52[b]	8.56
E + P	7.74	8.01[b]	7.87
E + H + P	8.66	9.51[ab]	9.08
CD ($P = 0.05$)	NS	1.34	NS
Pectinophora gossypiella moth catches/3 nights			
P alone	11.60	12.29	11.95
P + H	11.32	12.59	11.95
P + E	10.72	11.60	11.16
P + H + E	10.48	10.97	10.72
CD ($P = 0.05$)	NS	NS	NS

Figures with different letters in vertical columns are statistically significant.
H, *Helicoverpa armigera* pheromone trap
E, *Earias* spp. pheromone trap
P, *Pectinophora gossypiella* pheromone trap

Spotted bollworm (SBW), *Earias vittella* and *E. insulana*; and Pink bollworm (PBW), *Pectinophora gossypiella*. Hence the effect of different combinations of trap placement for collecting the different bollworms on a single bamboo pole in a cotton field was studied.

MATERIALS AND METHODS

The study was conducted in farmers' field at Rangri village, Sirsa, Haryana, during 2004 and 2005, with prevalent cotton varieties/hybrids. Three separate experiments were laid out with four treatments each replicated five times. First experiment had four treatments i.e. the traps of ABW alone (H), traps of ABW + SBW (H + E), traps of ABW + PBW (H + P) and traps of ABW + PBW + SBW (H + P + E). In the same way the second (E alone, E + H, E + P and E + H + P) and third (P alone, P + H, P + E and P + H + E) also had four treatments in each. In all the experiments

TABLE 2. Economics of integration of different pheromone traps (Cost in Rs./ha)

Operation (placement of 3 types of trap @5/ha)	Bamboo/ha		Labour/ha				Labour cost @Rs70	Total cost Rs.
				Monitoring				
	No.	Cost (Rs.)	Install-ation	Man day/ week	Man day/ season	Total		
Integrated placement	5	50/-	1	0.5	8	9	630	680
Individual placement	15	150/-	1	1	16	17	1190	1340

the height of the pheromone traps were fixed at 20 cm above crop canopy for pink bollworm (Korat and Lingappa, 1996), and 40 cm for spotted bollworm (Rajendran, 1999) and 60 cm for American bollworm (Dhanorkar and Puri, 1993). These traps were placed from 45 days after sowing of the crop and continued up to harvest (for four months). The traps were placed 40 m apart to accommodate 5 traps in a hectare. Each experiment was laid out in 4 ha cotton field.

The traps and lures procured from Pest Control India Ltd., Bangalore were used in this experiment. The lures were changed at monthly intervals in all the traps. The adult catches were counted in each and every trap after three nights and then these adults were removed from the trap. The data were analysed statistically.

RESULTS AND DISCUSSION

The results of moth catches in *H. armigera* (Table 1) indicated that the moth catches (moths/3 nights) were influenced by pheromones of other two species, when tied together. In both the years (2004 and 2005), the catches were at par in H alone, H + E and H + E + P. However, it was significantly less (3.50–3.95), when tied along with P.

In case of trap catches (moths/3 night) of *Earias* spp. (Table 1) in both the years the trap catches were more in E alone (9.72 and 10.33, respectively). In 2005, the moth catches (moths/3 nights) in E alone was at par with that of E + H + P (9.51), but was significantly higher than E + H (8.52) and E + P (8.01). In both the years, it was observed that trap catches were less in E + P (7.74 and 8.01, respectively) when compared to other combinations. Though the trap catches of *P. gossypiella* (moths/3 nights) remained higher in P alone (11.60 and 12.29) and P + H (11.32 and 12.59) compared to other treatments in both the years, 2004 and 2005, respectively (Table 1), the differences among the treatments were statistically non significant. The pooled analysis of different trap catches showed that the trap catches of their respective moths were more when the traps were placed individually *viz.*, H, E and P (5.31, 10.30 and

11.95 moths/3 nights respectively) but the differences among different combinations were statistically non significant.

It is evident from the present study that ABW or SBW traps when placed alone or in combinations did not affect their respective moth catches, however, the catches were negatively influenced when they were placed along with PBW traps (H + P or E + P). But, this negative effect of PBW on ABW and SBW was masked when all the three traps (H + P + E treatment) were placed together. It needs further investigation why the chemicals in PBW pheromone traps are interfering with that of ABW and SBW and reducing their efficiency, without any adverse effect on catches of PBW.

The present study revealed that there was one-third reduction in number of bamboos when the traps were placed in combination. In terms of labour (especially the maintenance of traps) the cost incurred was Rs. 630 when the traps were placed in combination, which was about half the cost of Rs. 1190 incurred in placing the traps individually (Table 2).

The results of the present study pave the way for recommending the placement of all the three traps in a single bamboo at different heights without sacrificing trap information and economizing on monitoring effect.

REFERENCES

Dhanorkar, B. K. and Puri, S. N. (1993) Monitoring of cotton bollworms using sex pheromone Traps in Marathwada. *Journal of Cotton Research and Development* 7: 171–173.

Dunkelblum, E. and Kehat, M. (1989) Female sex pheromone components of *Heliothis peltigera* (Lepidoptera: Noctuidae). Chemical identification from gland extracts and male response. *Journal of Chemical Ecology* 15: 2233–2245.

Korat, D. M. and Lingappa, S. (1996) Monitoring of pink bollworm moths with sex pheromone traps and its relationship with larval population and field Incidence. *Karnataka Journal of Agricultural Sciences* 9: 432–437.

Park, K. C., Boo, K. S., Cork, A. and Hall, D. R. (1994) Biological activity of female sex pheromone of the oriental tobacco budworm, *Helicoverpa assulta* (GueneÂ) (Lepidoptera: Noctuidae): Electroantennography, wind tunnel observation and field trapping. *Korean Journal of Applied Entomology* 33: 26–32.

Rajendran, T.P. (1999) Historical perspective, present scenario and future strategies of cotton pest management. URL:`http://www.indiaagronet.com/indiaagronet/pest_management/CONTENTS/insecticide__managemen.htm`

Rosaiah, B. and Reddy, A. S. (1995) Studies on sex pheromone trapping of *Helicoverpa armigera* Hubner on cotton. In: *Proceeding of National workshop on Pheromone in Integrated Pest management*, 45–48.

Tamhankar, A. J., Rajendran, T. P., Hariprasad Rao, N., Lavekar, R. C., Jeyakumar, P., Monga, D. and Bambawale, O. M. (2003) Variability in response of *Helicoverpa armigera* males from different locations in India to varying blends of female sex pheromone suggests male sex pheromone response polymorphism. *Current Science* 84: 448–450.

(Received 20 May 2006; accepted 15 September 2008)

ENTOMON 33(4): 241–251 (2008)
Article No. ent.33404

On some cucujoid beetles of Andaman and Nicobar Islands, India, with four new species (Coleoptera: Discolomidae, Erotylidae, Propalticidae)

T. K. Pal

Zoological Survey of India, M-Block, New Alipore, Kolkata 700 053, India
Email: tkpal51@rediffmail.com

ABSTRACT: Four new species *viz.*, *Aphanocephalus punctipennis* sp. nov., *A. shompen* sp. nov. [Discolomidae], *Spondotriplax tungus* sp. nov. [Erotylidae], and *Propalticus jarawa* [Propalticidae] are described from Andaman and Nicobar Is. Their distinction from other related species and a key to the species of the discolomid genus, *Aphanocephalus* Wollaston from India are given.

KEYWORDS: Coleoptera, Discolomidae, Erotylidae, Propalticidae, new species, Andaman and Nicobar Is

INTRODUCTION

The tropical moist forests in Andaman Is. are believed to contain an immense diversity of insects and good explorations would yield many curious and rare forms. This has been apparent from the finding of interesting forms of several families of Cucujoidea, the species of which were hardly known from this insular territory of India. During a recent field work in Andaman and Nicobar Is. several species of Discolomidae, Erotylidae and Propalticidae, including four new species, were found and these are described in this paper.

The Discolomidae (= Notiophygidae) are a moderately large family of Cucujoidea with more than 400 species under 18 genera from tropical and subtropical parts of the Old and New Worlds. Recently, Pal (2007) described four new discolomid species from West Africa and Indonesia from an old collection of material in Genova Museum. Pal (1992b) recorded this family in India from Arunachal Pradesh with two species of the genera, *Aphanocephalus* Wollaston and *Paramaschema* Heller and subsequently he (1996, 2000, 2005) described five more species from Sikkim, Mizoram and Nagaland. With the two new species from Andaman & Nicobar Is. the number of species of *Aphanocephalus* from India comes to 8.

The Erotylidae with about 2500 species have world-wide distribution with more abundance in warmer parts of both the Old and New worlds and with a fewer representatives from the temperate parts. The representatives of Erotylidae are small to large, elongate-ovoid, generally brightly coloured and are commonly called 'pleasing fungus beetles'. They usually feed on certain basidiomycetes, with adult and larvae sometimes found together. They are often found in moist woodland areas and adult beetles are generally gregarious. After the publication of Arrow's 'Fauna' in 1925 not much work has come out from the Indian subregion. Pal (1992a) described two species from Arunachal Pradesh. A new species of *Spondotriplax* Crotch from Great Nicobar Is. is described in this paper.

The Propalticidae are a small family with about 35 species under two genera (*Propalticus* Sharp and *Discogenia* Kolbe) and are represented in tropical Africa, Pacific islands, Australia and India (state of Sikkim). They are minute (1.0–1.5 mm), often live under bark of felled trees and seem to be mycophagous. Adults are capable of jumping using the front legs (Lawrence, 1982). Crowson (1955) erected the family Propalticidae for *Propalticus* and John (1960) added *Discogenia* to it. Sengupta (1978) recorded the family from India with a species of *Propalticus* from the lower altitude of Sikkim. The present study adds a new species of *Propalticus* from Andaman Is. to the Indian fauna.

SYSTEMATIC ACCOUNT

Family DISCOLOMIDAE

Genus *Aphanocephalus* Wollaston

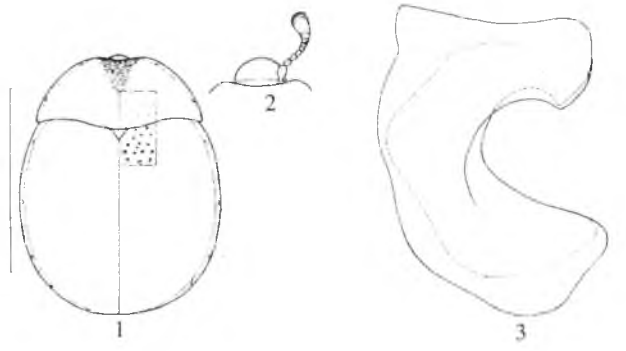
Aphanocephalus Wollaston, 1913, *Ent. Mon. Mag.* **9**: 278 (Type: *hemisphaericus* Wollaston).

Diagnosis: Body broadly ovoid, strongly convex dorsally and flattened ventrally, glabrous vestiture often with minute seate not generally visible at lower magnification; transverse head concealed largely by prothorax, 9-segmented antenna with a large club; strongly transverse prothorax with weakly rounded and smooth lateral sides, front coxal cavities closed behind, mesocoxal cavities closed and strernal fitting in a straight line, hind coxae globular and widely separated; tarsi 3-3-3; abdomen with broad intercoxal process and freely articulated ventrites.

Aphanocephalus sikkima Pal

Aphanocephalus sikkima Pal, 1997, *Hexapoda* **8(1)**: 10.

Diagnosis: Body oblong-ovate, about 1.2x longer than broad, convex, shiny, finely punctate-pubescent, uniformly dark reddish-brown except for paler front margin of pronotum. Head almost concealed from above by pronotum, fronto-clypeal suture situated just in front of antennal bases; antennal club large, elongate, more than one-third as long as antenna, with two pre-apical annulations, strongly transverse prothorax



FIGURES 1–3. *Aphanocephalus punctipennis* sp. nov.: 1, Dorsal view (scale 1 mm); 2, Exposed part of head and antenna; 3, Aedeagus, lateral view.

slightly emarginate in front, lateral margin feebly rounded and finely bordered, two pairs of lateral pits close to antero-lateral and posterior angles; elytra about as broad as long, punctures simple and point-like impressions on cuticle. Length 1.86–2.08 mm.

Material: 12 ex. Andaman Is., S. Andaman, Austinabad, 15 km. 0- Port Blair, 3 ex. 27.ix.2003, T.K. Pal, *ex.* sweeping bush; S. Andaman, Calicut, 15 km. 0- Port Blair, 9 ex., 26.ix.2003, T.K. Pal, *ex.* haystack.

Distribution: India: Sikkim, Andaman Is. (New record).

***Aphanocephalus punctipennis* sp. nov.**

General appearance (Fig. 1) oblong, ovate, about 1.2x as long as broad, convex dorsally and flattened ventrally, shiny, pronotal disc finely and elytra somewhat coarsely punctate, yellowish-brown to dark brown, darker triangular spot on antero-median part of pronotum.

Head small, exposed part distinctly transverse, largely concealed from above by pronotum, fronto-clypeal suture situated just in front of antennal insertions, less distinctly impressed, clypeus with pubescence; eyes moderately large, visible only from ventral side. Antenna (Fig. 2) short, shorter than pronotum, scape moderately large, pedicel and segment 3 narrower and little elongate, segment 4–7 short and subequal, segment 8 little wider than 7, club large, elongate, slightly shorter than one-third as long as antenna, with single preapical annulation.

Prothorax strongly transverse (1.0:2.3), narrowed in front, front margin feebly emarginate, front angles bluntly rounded, lateral margin arched and finely bordered, two small lateral pits situated close to anterior angle and at posterior third, posterior angles acute, basal margin distinctly sinuate on either side of middle, antero-median part of pronotum with a triangular darker spot; puncturation fine and sparse, devoid of pubescence.

Elytra slightly broader than long (1.0:2.3), more than twice (2.6:1.0) as long as prothorax, basal margin emarginate and fitting closely with prothorax, humeral angles blunt, widest near middle, sides evenly rounded, bordered and little explanate, unicolourous; punctures simple, about as coarse as eye facets, separated by 2–3 diameter, devoid of pubescence, six pit-like punctures arranged along elytral border.

Ventral side slightly paler, prosternum indistinctly punctate, metasternum with moderately large and dense punctures, little weaker mesally, punctuation on abdominal ventrite 1 coarser than on ventrites 2–5; legs yellowish-brown; epipleura flat, broad basally and acute for entire length.

Aedeagus (Fig. 3) on one side, median lobe forming a broad tube with broad and blunt tip; tegmen forming a cap-piece enveloping median lobe, its proximal end broad cap-like, its distal end broad and blunt.

Measurements of holotype: Total length 1.33 mm, width of head across eyes 0.40 mm, length of antenna 0.39 mm, length and width of prothorax 0.40 mm and 0.92 mm, length and width of elytra 1.04 mm and 1.06 mm.

Types: Holotype ♂, India, Andaman Is., South Andaman, Wimberligunj, 15.x.2003, T.K. Pal, *ex.* rotting log (Aedeagus dissected, mounted on a cover slip and pinned with the holotype); *Paratypes*, 3 ex., same data as holotype; *Paratypes*, 4 ex., Chatham Saw Mill, 25.ix.2003, T.K. Pal, *ex.* under bark (Zoological survey of India).

Etymology : The species name refers to the coarse punctures on elytra.

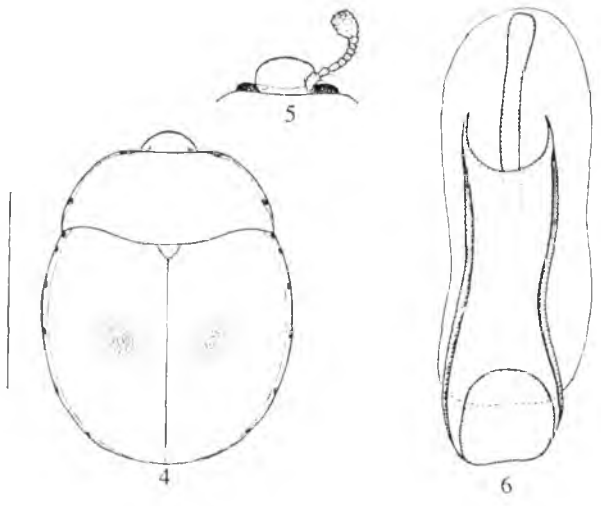
Remarks: This species shows certain resemblances with the Sumateran species, *Aphanocephalus distinctus* Grouvelle in having similar fancies and coarser elytral punctures than pronotum. But it differs from *distinctus* in having much coarser elytral punctures, side margins of prothorax uniformly curved and not little angulate prebasally as in *distinctus*. The aedeagus of this species with broad blunt tegminal tip differs from other known species of *Aphanocephalus* (aedeagus of *distinctus* is not described).

Aphanocephalus shompen sp. nov.

General appearance (Fig. 4) oblong-ovate about 1.2x as long as broad, convex dorsally and flattened ventrally, shiny, glabrous, inconspicuously punctate, dark brown with paired orbicular paler spots on elytra.

Head small, exposed part transverse, partly concealed from above by pronotum, fronto-clypeal suture situated just in front of antennal bases, clypeus sparsely setose; eyes moderately large, but partly visible from dorsal side. Antenna (Fig. 5) short, about as long as pronotum, scape moderately large, pedicel and segment 3 narrower and little elongate, segment 4–7 short and subequal, segment 8 little wider; club large, elongate, shorter than one-third as long as antenna, with single preapical annulation.

Prothorax strongly transverse (1.0:2.2), narrowed in front, front margin almost un-



FIGURES 4–6. *Aphanocephalus shompen* sp. nov.: 4. Dorsal view (scale 1 mm); 5. Exposed part of head and antenna; 6. Aedeagus, dorsal view.

emarginate, front angles bluntly rounded, lateral margin feebly arched and bordered, two lateral pits situated close to anterior angle and behind middle, posterior angles acute, basal margin distinctly sinuate on either side of middle, puncturation inconspicuous on pronotum and devoid of setae.

Elytra about as broad as long, about 2.8x as long as prothorax, basal margin emarginate and fitting closely with prothorax, humeral angles blunt, widest near middle, sides evenly rounded, bordered and little explanate; a pair of admedian, orbicular paler spots near middle, edges of which are not well defined, punctuation inconspicuous and devoid of setae, six large pit-like punctures present along elytral border.

Ventral side not paler than dorsal side, prosternum and mesosternum impunctate and glabrous, metasternum with moderately coarse punctures but impuctate mesally, punctuation on abdominal ventrites almost similar to that of sides of metasternum and finely setose; legs dark-brown; epipleura flat, broad basally and acute for entire length.

Aedeagus (Fig. 6) not turned on one side, distal end of median lobe broadened with a large orifice, its proximal end concave with a strut, tegmen forming a cap-piece enveloping large part of median lobe leaving only its distal part.

Measurements of holotype: Total length 1.48 mm, width of head across eyes 0.38 mm, length of antenna 0.41 mm, length and width of prothorax 0.40 mm and 0.97 mm, length and width of elytra 1.13 mm and 1.11 mm.

Types: *Holotype* ♂, India, Nicobar Is., Great Nicobar, Sital Pahar, 15 km. 0-Campbell Bay, 10.x.2003, T.K. Pal, *ex.* fallen log (Aedeagus dissected, mounted on a cover slip and pinned with the holotype); *Paratypes*, 7 ex., same data as holotype; *Paratypes*, 7 ex., Great Nicobar, Campbell Bay, 7.x.2003, T.K. Pal, *ex.* under bark (Zoological survey of India).

Etymoloy: The species is named after 'Shompen', the indigenous tribe of Great Nicobar Is.

Remarks: This species shows some resemblances with *Aphanocephalus maculipennis* Pal from Mizoram in having hemispherical lighter areas on elytra. But it differs from *maculipennis* by its dorsum darker and glabrous, puncturation on pronotum and elytra finer and almost inconspicuous, no lighter areas on pronotum and elytra except paired hemispherical spots on elytra, antennae not lighter than dorsum; structure of aedeagus different with median lobe straight and not bent near middle.

KEY TO THE SPECIES OF *APHANOCEPHALUS* WOLLASTON FROM INDIA

1. Front margin of prothorax rather deeply and widely emarginate, one pair of lateral marginal pits of pronotum present near humeral angles and those near basal third absent ..... *superbus* Pal
– Front margin of prothorax either unemarginate or slightly emarginate, two pairs of lateral marginal pits near humeral angles and near basal third absent..... **2**
2. Antennal club segment with single preapical annulation **3**
– Antennal club segment with two preapical annulations **7**
3. A air of median hemispherical paler spots on elytra **4**
– Elytra devoid of hemispherical paler spots and dark throughout, margins narrowly paler occasionally **5**
4. Pronotum and elytra finely punctate and setose, periphery of pronotum and elytra paler than middle in addition to hemispherical paired spots on elytra, antenna paler than dorsum; aedeagus turned on one side, median lobe broad and bent near middle ..... *maculipennis* Pal.
– Pronotum and elytra almost impunctate, glabrous and shiny, no paler area on pronotum except hemispherical paired lighter spots on elytra, antenna not paler than dorsum; aedeagus not turned on one side, median lobe almost straight and not bent near middle ..... *shompen* sp. nov.
5. Antero-median part of pronotum triangularly darker, remaining part of disc paler; elytra coarsely punctate and much coarser than pronotum .. *punctipennis* sp. nov
– Larger part of pronotum darker, sides or margins variably paler; elytral punctures generally fine, if slightly coarse not markedly coarser than pronotal punctures . **6**
6. Front and side margins of pronotum with broad, uninterrupted paler band; aedeagus with distal end of tegument bifid..... *convexus* Pal

– Narrow paler bands on antero-lateral part of pronotum which extend posterad towards middle; aedeagus with distal end of tegumen spatulate and be set with setae ..... *angulus* Pal

7. Antero-lateral pale border of pronotum uninterrupted and continuous throughout its length; aedeagus with distal end of median lobe narrowed and rather broadly pointed ..... *johni* Pal

– Antero-lateral pale border of pronotum uninterrupted near middle, along front margin; aedeagus with distal end of median lobe broad and blunt ... *sikkima* Pal

Family EROTYLIDAE

Subfamily EROTYLINAE

Tribe TRITOMINI

Genus *Spondotriplax* Crotch

Spondotriplax Crotch, 1876, *Cistula Entomologica*, **1**: 469 (Type: *Spondotriplax endomychoides* Crotch).
Neotritoma Heller, 1918, *Archiv für Naturgeschicte* (Ser. A), **1918**: 28.

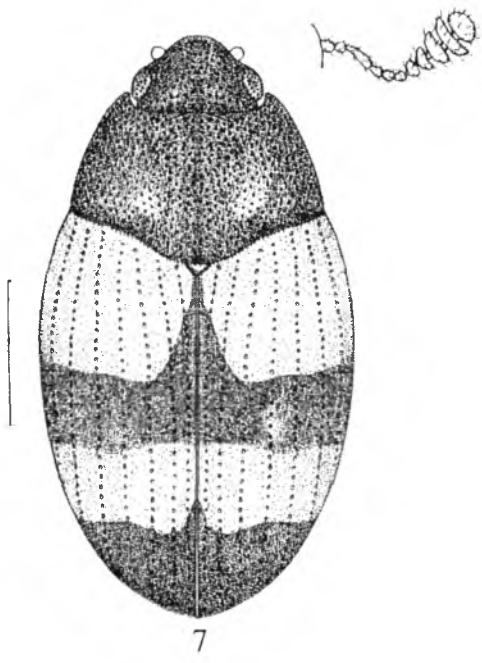
Diagnosis: Facies broadly ovoid, rather convex, head broad with large eyes, 11-segmented antenna with 5-segmented club, sides of mouth cavity moderately dilated, apical segment of maxillary palpi moderately transverse; transverse prothorax with front coxae widely separated, mesocoxae with femoral lines, elytra with linear punctures.

***Spondotriplax tungus* sp. nov.**

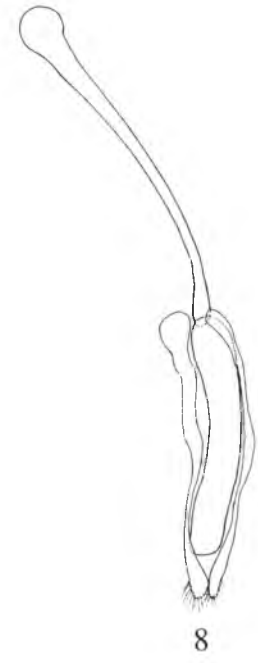
General appearance (Fig. 7) elongate-ovoid, convex with moderately long legs and antennae, dorsum shining and smooth; head and pronotum blackish, sides of pronotum occasionally faint orange-coloured, two pairs of subquadrate orange spots on blackish elytra, antennae blackish and legs reddish.

Head broader than long, apical margin of clypeus truncate; eyes moderately large, moderately finely facetted, separated dorsally by about 2.6x of its length; antennal bases widely separated; puncturation on vertex moderately coarse and dense, separated by about 1–2 diameter, puncturation on clypeus slightly finer. Antenna moderately long and slender, scape moderately large and broadly elongate, pedicel shorter and narrower than scape, segment 3 about as long as segments 4–6; club 5-segmented, slightly asymmetrical, last three segments much broader than preceding two segments.

Prothorax transverse (1.0:1.6), widest at base, moderately narrowed anteriorly, sides evenly rounded, front margin deeply emarginated with fine elevation of pronotum at middle, front angles produced and forming acute angles, lateral margin finely bordered; basal margin bi-emarginate with broad median lobe, no prebasal impression; pronotal disc moderately coarsely and densely punctuate, punctures separated by 1–2 diameter.



7



8

FIGURES 7–8. 7, *Spondotriplax tungus*, sp. nov., Dorsal view, right antenna shown separately (scale 1 mm). 8, *Spondotriplax tungus*, sp. nov., Aedeagus, dorsal view (slightly tilted leftwards).

Scutellum triangular, transverse and finely punctuate.

Elytra broadly elongate, about as wide as prothorax at base and closely fitting with it, sides evenly rounded to apex, lateral edges very narrowly flanked ansd finely bordered; distinct puncture rows visible, eight in number; blackish elytra decorated with two transverse orange spots: one in basal half and other in apical third, blackish patches extend along suture and form divider between either half.

Ventral side reddish, pro- to metasternum with fine and sparse punctures, punctures on abdominal ventrites slightly coarser.

Aedeagus (Fig. 8) with median lobe long, tubular and curved, from base of median lobe arises long, slender median strut, tegminal cap formed of a pair of elongated lateral lobes and apices of which setose.

Measurements of holotype: Total length 3.08 mm, width of head across eyes 0.84 mm., length of antenna 1.12 mm., length and width of prothorax 0.84 mm. and 1.50 mm., length and width of elytra 2.28 mm. and 1.80 mm.

Types: Holotype ♂, India, Nicobar Is., Great Nicobar, Sital Pahar, 15 km-O Campbell Bay, 10.x.2003, T.K. Pal, *ex.* fallen log (Aedeagus dissected, mounted on

a cover slip and pinned with the holotype); *Paratypes*, 10 ex., locality data same as holotype (Zoological Survey of India).

Etymology: The species name is derived from Anglo-Saxon 'tungue' for tongue, referring to the tongue-like median lobe of aedeagus.

Remarks: This species shows some resemblances with *Spondotriplax diaperina* Gorham [from Myanmar] and *S. andamana* Arrow [from Andaman Is.]. It differs from *S. diaperina* in having orange spots in basal half of elytra without angular lobes at posterior borders, humeral angles of elytra devoid of any blackish spot (vs. presence of humeral spot in *diaperina*), antennae entirely blackish. It differs from *S. andamana* by its head and prothorax blackish (vs. orange-coloured in *andamana*), two pairs of subquadrate orange spots on elytra (vs. four pairs of blackish spots on each elytron in addition to two sutural spots in *andamana*).

Family PROPALTICIDAE

Genus *Propalticus* Sharp

Propalticus Sharp, 1879, *Ent. Soc. Lond., Trans.* **1879**: 88 [Type: *Propalticus oculatus* Sharp].

Diagnosis: Facies elongated, broadly ovoid, dorsally more or less dull; head transverse with large eyes, filamentous antennae with 3-segmented loose club, no fronto-clypeal suture; large transverse prothorax with a median longitudinal impression, front margin emarginate, front coxae widely separated and cavities externally open; mesosternum short, mesocoxal cavities broadly closed outwardly by sterna; metasternum strongly transverse, hind coxae widely separated; large spur on tibia of front leg; elytra broad-ovoid, with longitudinal striae, epipleurae well developed and complete up to apex; abdominal ventrites freely articulated, intercoxal process broad and truncate, no femoral lines.

Propalticus jarawa sp. nov.

General appearance (Fig. 9) elongate, broad-oval, subdepressed, dark brown, dull, with short fine, recumbent pubescence; apex of abdomen exposed.

Head large, transverse, widest across eyes, inserted into prothorax, front margin of clypeus emarginate, labrum exposed; antennal insertions dorsally on sides, 11-segmented antenna, scape and pedicel large, segments 3–8 slender and more or less elongate, 3-segmented loose club of which segments 9 and 11 elongate and segment 10 about as broad as long, segments 1-2 and 9-11 darker than remaining segments; eyes large, projecting, bean-shaped, more than half as long as head, rather finely facetted; no tempora, distinct transverse line on vertex immediately behind eyes, vertex and clypeus finely pubescent.

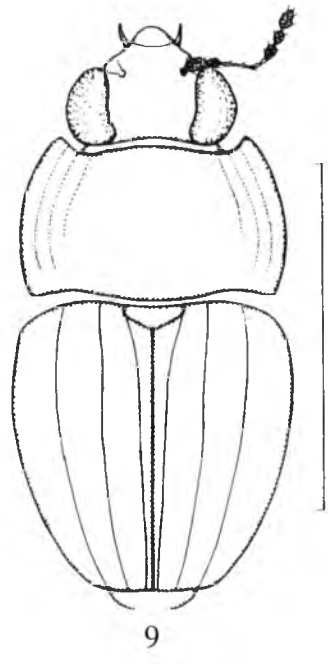


FIGURE 9. *Propalticus jarawa*, sp. nov., Dorsal view (scale 1 mm).

Prothorax large, transverse (1.0:1.7), wider posteriorly, sides arched, front margin emarginate and slightly sinuate on sides, front angles well marked and acute, hind margin sinuate on sides and hind angles less well marked, sides smooth and finely bordered; disc with a median impressed line, three longitudinal sublateral carinae on either side, outer two carinae continue from front to near base and the inner one shorter, surface finely pubescent.

Scutellum large, transverse, angulate apically.

Elytra fit well with base of prothorax, about 1.07x as long as broad, sides arched, finely flanked and narrowed behind one-third, apex of elytra not separately rounded, elytral shoulders obtuse, three longitudinal striae on each elytron continued from base to apex, surface finely pubescent; tip of abdomen exposed.

Measurements of holotype: Total length 1.58 mm., width of head across eyes 0.50 mm., length of antenna 0.40 mm., length and width of prothorax 0.44 mm. and 0.79 mm., length and width of elytra 0.88 mm. and 0.82 mm.

Holotype: 1 ex., India: Andaman Is., S. Andaman, Chatham, Port Blair, 13.ii.2000, T.K. Pal & party, *ex.* under bark (Zoological Survey of India, Kolkata).

Etymology: The species is named after 'Jarawas', the primitive tribe of Andaman Is. where the species has been found.

Remarks: This species differs from the other Indian species, *Propalticus indicus* Sengupta by its apical margin of clypeus emarginated, pronotum with three longitudinal sublateral carinae on either side, three striae on each elytron complete from base to apex. This species also shows some resemblances with *P. oculatus* Sharp [Hawaii and Pacific Islands] but can be differentiated by its pronotum with three pairs of sublateral carinae, elytra devoid of any submedian spot and elytral apices are not separately rounded.

ACKNOWLEDGEMENTS

I am indebted to the Director, Zoological Survey of India, Kolkata for providing necessary facilities to carry out this work. I acknowledge the support extended by my colleague, B. Baraik during the field work and S. Biswas in art of the habitus figure of the new species of Erotylidae.

REFERENCES

Arrow, G. J. (1925) *The Fauna of British India, including Ceylon and Burma*, Coleoptera: Clavicornia (Erotylidae, Languriidae and Endomychidae). xv+416 pp., 1 pl., 1 map, Taylor & Francis, London.

Crowson, R. A. (1955) *The Natural classification of the families of Coleoptera*, Nathaniel Lloyd & Co., London.

John, H. (1960) Eine übersicht über die familie Propalticidae (Col.). *Pacific Insects* 2(2): 149–170.

Lawrence, J. F. (1982) Coleoptera. In: *Synopsis and Classification of Living Organisms*, Parker, S. P. (Ed). McGraw-Hill, New York, vol. 2: 482–553.

Pal, T. K. (1992a) On a collection of Clavicorn beetles (Families Erotylidae, Endomychidae and Languriidae) from Arunachal Pradesh, India. *Records of the Zoological Survey of India* 90(1-4): 203–210.

Pal, T. K. (1992b) Discolomidae, a beetle family new from India. *Hexapoda* 4(1): 45–56.

Pal, T. K. (1996) Three new species of Discolomidae (Coleoptera: Clavicornia) from Sikkim. *Hexapoda* 8(1): 9–17.

Pal, T. K. (2000) A new species of Discolomidae from Mizoram, India (Coleoptera: Cucujoidea). *Entomon* 25(4): 287–291.

Pal, T. K. (2005) Discolomidae of Nagaland, India with description of a new species (Coleoptera: Cucujoidea). *Entomon* 30(4): 297–301.

Pal, T. K. (2007) On a collection of Heteromera and Cucujoidea of the Museo Civico di Storia Naturale G. Doria, Genova (Coleoptera, Polyphaga). *Annali del Museo Civico di Storia Naturale G. Doria* 89: 193–221.

Sengupta, T. (1978) Discovery of the family Propalticidae (Coleoptera) from India, with description of a new species of *Propalticus*. *Oriental Insects* 12(1): 81–83.

(Received 11 November 2008; accepted 30 November 2008)

ENTOMON 33(4): 253–257 (2008)
Article No. ent.33405

A new species of *Trichogramma* Westwood (Hymenoptera: Trichogrammatidae) from Chhattisgarh, India

Mohammad Yousuf* and Md. Ehtashamul Hassan

Forest Entomology Division, Tropical Forest Research Institute, Jabalpur 482 021, M.P., India
Email: yousuf_tfri@yahoo.com

ABSTRACT: A new species of *Trichogramma*, *T. kankerensis* sp. n. is described and illustrated. *T. kankerensis* is closely related to *T. achaeae* Nagaraja & Nagarkatti by having its male genitalia with chelate structures reaching to the level of tips of gonoforceps and median ventral projection very minute and inconspicuous; but can be distinguished from the latter by having its male antennae with relatively short and uniformly tapering flagellar hairs, about two times as long as maximum flagellar width. Male genital capsule is broad, about two times as long as wide, and aedeagus as long as apodemes.

KEYWORDS: Hymenoptera, Trichogrammatidae, Trichogramma kankerensis, *Trichogramma achaeae*

INTRODUCTION

Trichogramma wasps parasitize insect eggs, especially eggs of moths and butterflies and are widely utilized for applied biological control. Members of the family Trichogrammatidae are very minute, 0.2 to 1.0 mm in length. *Trichogramma* spp. are easily recognized by having female antennae with 2-segmented funicle and one segmented club; fore wings with sigmoid venation, and presence of vein track RS1 (Doutt and Viggiani, 1968; Yousuf and Shafee, 1987). This genus was erected by Westwood in 1833, with the type species *Trichogramma evanescens*. Several new species of *Trichogramma* have been described from India since then. These include *T. flandersi*, *T. chilotraeae*, *T. achaeae* (Nagaraja and Nagarkatti, 1969), *T. hesperidis*, *T. agriae*, *T. pallidiventris*, *T. plasseyensis*, *T. poliae*, *T. raoi* (Nagaraja, 1973), *T. brevifringiata* (Yousuf and Shafee, 1987), *T. manii* (Nagaraja and Gupta, 2007), *T. kashmirica* (Nagaraja *et al.*, 2007), and*T. breviciliata* (Yousuf and Hassan, 2007). In

*Corresponding author

addition, Nagaraja (1996) has published five new species from India. Morphometric and additional diagnostic characters of *T. plasseyensis* Nagaraja were given by Hassan and Yousuf (2007). Nagaraja *et al.* (2008) investigated the true identity of *T. brasiliensis* used in India since early 1970s and concluded that it is a thelytokous form of *T. pretiosum*. Taxonomic studies play an important role in correct identification of the parasitoids, before their field release. A new species, *Trichogramma kankerensis* sp.n. is described and illustrated here.

MATERIALS AND METHODS

Collections of *Trichogramma* were made from forests and adjoining agro-forestry areas of Madhya Pradesh, Chhattisgarh, Maharashtra and Orissa. Two methods, sweeping and trapping in *Corcyra cephalonica* eggs, were followed. Sweeping was carried out in green areas near water bodies and green patches of forests and agro-forestry lands. The samples of collected insect fauna were preserved in 70 % alcohol and examined thoroughly under stereoscopic microscope for sorting the *Trichogramma* spp. Following the normal course of dehydration, the specimens were cleared in clove oil and dissected under stereoscopic binocular microscope for studying the important taxonomic characters. Drawings were prepared with the help of Camera Lucida. Identification was carried out using all conventional and genitalic characters.

GENUS *TRICHOGRAMMA* WESTWOOD, 1833

***Trichogramma* Westwood, 1833: 444.**

Type-species: *Trichogramma evanescens* Westwood, by monotypy.

The genus *Trichogramma* Westwood is known to contain 154 species (Lin, 1994; Yousuf *et al.*, 2004), including one new species; of which 25 species have been recorded from India.

The new species *T. kankerensis* is closely related to *T. achaeae* Nagaraja & Nagarkatti, from which it can be easily separated by the following key characters.

1. Male antennal hairs about 2.5 times to the maximum width of flagellum; male genital capsule about 2.5 times as long as wide, aedeagus about one and a half times as long as apodemes ..... *T. achaeae* Nagaraja & Nagarkatti.

– Male antennal hairs about 2 times to the maximum width of flagellum; male genital capsule broad, about 2 times as long as wide, aedeagus as long as apodemes ..... *T. kankerensis* sp. n.

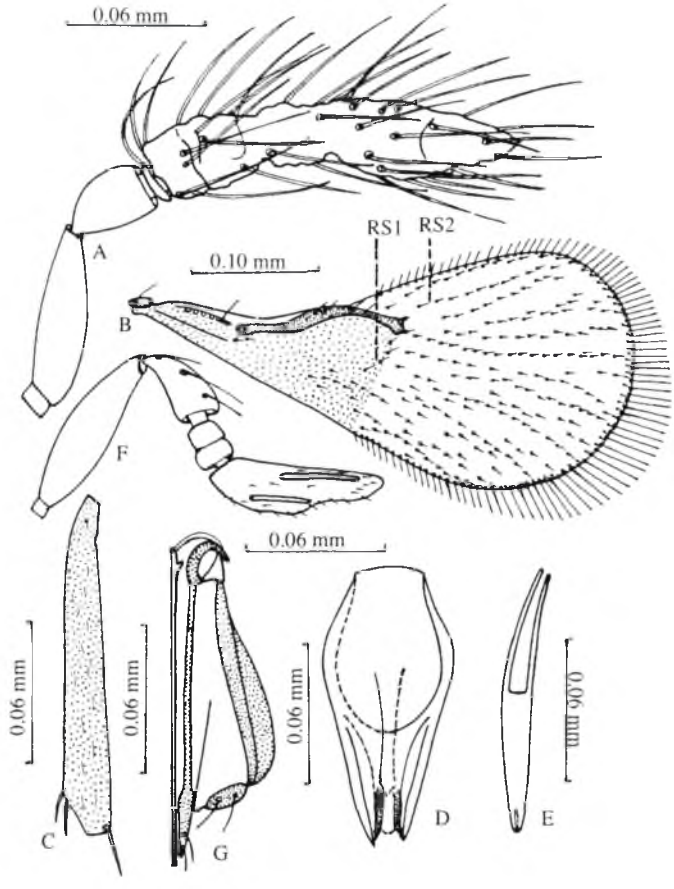


FIGURE 1. A–G. *Trichogramma kankerensis* sp. n. A. antenna ♂ B. fore wing ♂, C. hind tibia ♂, D. genitalia ♂, E. aedeagus ♂, F. antenna ♂, G. genitalia ♂.

TRICHOGRAMMA KANKERENSIS SP. N. (FIGURE 1A–G)

Male

Head dark brown, slightly wider than long in facial view; ocelli reddish, arranged in obtuse triangle, eyes red. Antennae (Fig. 1A) brown; scape cylindrical, about three and a half times as long as wide, pedicel about one and a half times as long as wide; single ring segment present; flagellum stout and about five times as long as wide; 35 short and uniformly tapering flagellar setae present; longest of which about two times as long as the maximum width of flagellum.

Thorax brown with fuscus sides of pronotum, mesonotum and pleurae. Fore wings (Fig. 1B) hyaline, except the area beneath venation infuscated, about two times as long as wide; disc densely setose, discal setae arranged in rows; costal cell broad; Vein track RS1 with four setae; RS2 with 11 setae; r-m with 20 setae; between RS2 & r-m 38 setae; marginal fringe long, about one fifth the wing width. Legs yellow with coxae darkly infuscated.

Abdomen brown, slightly longer than thorax; genitalia about two times as long as wide; with prominent well chitinized dorsal expansion of gonobase, this being almost triangular with blunt apex, behind the tip of gonoforceps; CS in the level of GF. MVP very minute and inconspicuous. Aedeagus (Fig. 1E) as long as apodemes, combined length of both aedeagus & apodemes is slightly shorter than the length of entire genitalia (Fig. 1D) and also shorter than hind tibia (Fig. 1C).

Body length: 0.48 mm.

Female

Body colour same as male. Antennae (Fig. 1F) brown; scape about three and a half times as long as wide; pedicel slightly less than two times as long as wide; funicle two-segmented, both segments combined slightly longer than wide; club solid; about three and a half times as long as wide. Ovipositor (Fig. 1G) hidden, tip of ovipositor slightly exserted; ovipositor as long as hind tibia.

Body length: 0.50 mm

Holotype ♂, allotype ♀. India: Chhattisgarh; Kanker, Garpichhori, 23.XI.2006; by trapping in *Corcyra cephalonica* eggs stripes, M. Yousuf.

Holotype and allotype have been deposited in National Forest Insect Collection (Acc. No. 21755), Entomology Division, FRI, Dehra Dun, India.

Etymology

Named after the district place, Kanker; from where the type material was collected.

Comments

The new species *T. kankerensis* is closely related to *T. achaeae* Nagaraja & Nagarkatti by having its male genitalia with chelate structures reaching to the level of the tips of gono-forceps and median ventral projection very minute and inconspicuous; but the former can easily be distinguished from the latter by having its male antennae with relatively short and blunt flagellar hairs, longest of which is about two times as long as maximum width of flagellum; male genital capsule broad, about two times as long as wide; aedeagus as long as apodemes.

ACKNOWLEDGEMENTS

We are greatly indebted to Dr. A. K. Mandal, Director, TFRI, Jabalpur, for providing necessary research facilities. We are also thankful to the Department of Science &

Technology, New Delhi; for providing the financial assistance (DST Project Sanction No. SR/SO/AS-34/2004). Thanks are also due to Dr. K. C. Joshi, Head, Forest Entomology Division, TFRI, Jabalpur for his valuable suggestions and constant encouragement.

REFERENCES

Doutt, R. L. and Viggiani, G. (1968) The classification of the Trichogrammatidae (Hym.: Chalcidoidea). *Proc. Calif. Acad. Sci.* 35: 477–586.

Hassan, E. and Yousuf, M. (2007) First record of *Trichogramma plasseyensis* Nagaraja (Hymenoptera: Trichogrammatidae) from central India, and its morphometric and additional diagnostic characters. *Indian. J. Ent.* 69(1): 56–62.

Lin, N. (1994) *Systematic studies of Chinese Trichogrammatidae (Hymenoptera: Chalcidoidea)*, special publication No. 4, Fujian Science and Technology publishing house, Fuzhou. Fujian. P.R. China, p. 362.

Nagaraja, H. (1973) On some new species of Indian *Trichogramma* (Hymenoptera: Trichogrammatidae). *Oriental Insects* 7(2): 275–290.

Nagaraja, H. (1996) Five more new species of Indian *Trichogramma* (Hymenoptera: Trichogrammatidae), with a host list and a key to species. *Colemania: Insect Biosystematics* 4: 01–11.

Nagaraja, H. and Nagarkatti, S. (1969) Three new species of *Trichogramma* (Hymenoptera: Trichogrammatidae) from India. *Entomophaga* 14(4): 393–400.

Nagaraja, H. and Gupta, A. (2007) A new species of *Trichogramma* (Hymenoptera: Trichogrammatidae) parasitic on eggs of pomegranate fruit borer, *Deudorix isocrates* (Fabricius) (Lepidoptera: Lycaenidae). *J. Biol. Control* 21(2): 291–293.

Nagaraja, H., Ahmad, J. and Gupta, A. (2007) A new species of *Trichogramma* (Hymenoptera: Trichogrammatidae) from Anantnag, Jammu & Kashmir, India. *J. Biol. Control* 21(2): 287–289.

Nagaraja, H., Gupta, A., Lalitha, Y., Mohanraj, P. and Jalali, S. K. (2008) On the true identity of "*Trichogramma brasiliensis* (Ashmead)" (Hymenoptera: Trichogrammatidae) being used in India. *J. Biol. Control* 22(2): 255–260.

Westwood, J. O. (1833) Description of several new British forms among the parasitic Hymenopterous insects. *Phil . Mag . J. Sci.* 2: 443–445.

Yousuf, M. and Shafee, S. A. (1987) Taxonomy of Indian Trichogrammatidae (Hymenoptera: Chalcidoidea). *Indian J. Syst. Entomol.* 4(2): 55–200.

Yousuf, M., Joshi, K. C. and Kulkarni, N. (2004) *Trichogramma*: The noble egg parasitoids, their success and potential in biological control of insect pests. In: *Contemporary Trends in Insect Science*, Gujar, G. T. (Ed). Campus Books Inter National, New Delhi, p. 424–369.

Yousuf, M. and Hassan, M. E. (2007) Record of one new species of *Trichogramma* Westwood (Hymenoptera: Trichogrammatidae) from Madhya Pradesh, India. *Bio. Sci. Res. Bull.* 23(1): 7–11.

(Received 19 August 2008; accepted 15 November 2008)

ENTOMON **33(4):** 259–266 (2008)
Article No. ent.33406

Screening of bivoltine breeds of the silkworm, *Bombyx mori* for relative tolerance to the white muscardine fungus, *Beauveria bassiana* (Bals.) Vuill.

K. Chandrasekharan* and B. Nataraju

Central Sericultural Research and Training Institute, , Mysore 570 008, Karnataka, India
Email: kchandrasekharan@rediffmail.com

ABSTRACT: Forty five bivoltine breeds of silkworm were screened against *Beauveria bassiana* to determine their relative tolerance against this pathogen. Based on their survivability after third moult, tolerance index (TI) of these breeds were determined and were categorised as highly tolerant (above mean + SD), moderately tolerant (between mean and mean + SD), moderately susceptible (between mean and mean - SD) and highly susceptible (below mean – SD). The TI ranged from 67.47 to 24.88. CSR51 with a TI of 67.47 stood first in rank followed by Diazo, CSR50, CSR5, MBN2 and CSR8 (SL). Six breeds *viz*., CSR17, A69, SBNP12, B62, CSR19 and CSR2 were highly susceptible. Out of the 45 breeds, 17 were moderately tolerant and 16 moderately susceptible. The LC_{50} value of the highly tolerant breed CSR51 was 14.48 times more than that of the highly susceptible CSR2 breed. Likewise, the days required for the pathogen to kill 50% of the population in CSR51 was 3.19 days more than that of CSR2 breed.

KEYWORDS: *Beauveria bassiana*, *Bombyx mori*, bivoltine, relative tolerance, white muscardine

INTRODUCTION

Though India is next only to China in silk production, the average cocoon productivity in India is comparatively low which is primarily due to crop loss on account of high disease incidence. Silkworm diseases are prevalent throughout the year and the incidence differs significantly among seasons. Selvakumar *et al.* (2002) reported a crop loss of around 11.5–15 kg/100 dfls at the point prevalence level. White muscardine caused by *Beauveria bassiana* (Bals.) Vuill. is the most devastating silkworm disease. It is rampant causing heavy economic loss in India especially in Karnataka, which is the major silk producing state in the country. The climatic condition in the tropics

*Corresponding author

is congenial for the incidence and easy spread of fungal diseases. Sustainability of sericulture depends upon successful realisation of cocoon crop throughout the year and to achieve this management of silkworm diseases is most important. Exploitation of the resistance/tolerance of silkworm towards different disease causing pathogens is a good option for managing the crop loss due to diseases. In silkworms, large difference exists among various strains in their susceptibility to infections by *B. bassiana* and *Aspergillus* sp. (Chinnaswamy and Devaiah, 1984).

Bivoltine sericulture is essential and important for the production of quality silk of international grade, but the inherent high susceptibility of the bivoltine breeds to different pathogens of silkworm is a major bottle neck in increasing the bivoltine productivity. To improve the productivity in bivoltine breeds, productivity traits and disease tolerance should be suitably combined by the silkworm breeders in order to exploit it at field level. Keeping this in view 45 bivoltine breeds were screened against *B. bassiana* to determine their relative tolerance and also to identify the tolerant breeds so as to use them in future breeding programs.

MATERIALS AND METHODS

Fourty five bivoltine breeds obtained from the Bivoltine breeding laboratory of Central Sericultural Research and Training Institute, Mysore were utilized for this study. The silkworm breeds were screened for their relative tolerance towards *B. bassiana*. Rearing was conducted till second moult as per standard young age rearing method on V1 variety of mulberry leaves. *B. bassiana* was cultured in Petri plates using Sabouraud's dextrose agar. Conidia were harvested by scrapping the surface of 3-week-old culture into a 500 ml glass beaker containing 50 ml sterile distilled water. A drop of tween-20 was then added to the beaker containing distilled water and conidia. The conidial suspension was prepared by mixing the solution using a magnetic stirrer for 5 min and was then diluted in sterilized distilled water to get the desired concentrations based on counts made with an improved Neubauer haemocytometer.

Newly ecdysed third instar larvae (out of second moult) were topically inoculated by dipping them in the *B. bassiana* inoculum suspension of 1×10^5 conidia/ml concentration. Larvae were kept in a sterile plastic tea strainer and dipped in the conidial suspension taken in a wide mouthed sterile beaker. The inoculum was stirred before each dipping and was changed after every ten dippings. The inoculated larvae were transferred to separate plastic rearing trays (90 cm × 60 cm) and reared on V1 mulberry leaves. Ambient relative humidity ($95 \pm 5\%$ RH) for the growth of the fungal pathogen was provided by keeping wet foam pads in the rearing tray and a temperature of 25 ± 1 °C was maintained in the rearing room.

Hundred larvae each were kept for each replication and 5 replications were maintained for each breed. Control batches were also maintained without any inoculation but with sterile water dipping, for comparison. Observations on the per cent larval survival were recorded for ten days and the diseased larvae were removed before mummification to avoid secondary contamination. The day of initial mortality and complete

mortality were also recorded. The experiment was repeated thrice and the data were pooled. The survival data were corrected using Abbots formula (Finney, 1971).

Estimation of tolerance and ranking of the breeds

A tolerance index (TI) on the survival after 5 days post inoculation was calculated based on the Evaluation Index proposed by Mano *et al.* (1998). Based on TI the breeds were ranked as highly tolerant (above mean survival in all the breeds + SD), moderately tolerant (between mean and mean + SD), moderately susceptible (between mean and mean – SD) and highly susceptible (below mean – SD).

Lethal concentration and lethal time of the selected breeds

Based on the disease incidence and Tolerance Index, two highly tolerant (CSR 51 and Diazo), two highly susceptible (CSR2 and CSR19) and one moderately tolerant (NB18) breeds among the bivoltines were selected and their LC_{50}, LC_{90}, LT_{50} and LT_{90} values were determined following Probit analysis procedure of Finney (1971).

RESULTS

The percent mortality due to white muscardine up to 5 day post inoculation (5 DPI) in the 45 breeds ranged from 14.51 to 84.15 which indicate the wide difference in their tolerance to the pathogen. But mortality range narrowed when days progressed and 10 days after inoculation (10 DPI) mortality was between 85.49 and 100%. Ten days after the inoculation larvae survived only in 4 breeds (CSR51, Daizo, CSR50 and CSR5). This indicates that difference in tolerance in the tested breeds against *B. bassiana* is prominently clear during the initial days and larvae in almost all the breeds succumbed to the infection when the days progressed. Hence, mortality up to 5 DPI was considered for identifying the relative tolerance status of the breeds. The mortality and survival data after 5 DPI are presented in Table 1. The survival after 5DPI ranged between 15.85 and 85.49% in the 45 breeds with 28.72 mean CV. Mortality started from the third day of inoculation in all the breeds except for two breeds (CSR51 and Daizo) where it started on the fourth day after inoculation. 100% mortality of the larvae in these breeds occurred from sixth day onwards and in 3 breeds larvae survived even after 10 days of inoculation. The lethal time for 50% mortality (LT_{50}) as indicated in the Table 1 ranged from 4.89 to 7.72 days in these breeds.

Based on the survival after 5DPI, a tolerance index (TI) was derived and the breeds were ranked from 1 to 45 (Table 1). The TI ranged from 67.47 to 24.88. CSR51 with a TI of 67.47 stood first in the rank followed by Diazo with 64.49 TI. CSR19 and CSR2 breeds were last in the rank with 28.26 and 24.88 TI, respectively. Based on the percent survival, the breeds were categorized into four groups *viz.* highly tolerant, moderately tolerant, moderately susceptible and highly susceptible as per the scale. Out of the 45 breeds, 6 breeds, *viz.*, CSR51, Diazo, CSR50, CSR5, MBN2 and CSR8(SL) were highly tolerant (>73.28% survival) and 6 breeds *viz.*, CSR17, A69, SBNP2, B62, CSR19 and CSR2 were highly susceptible (<40.58% survival). Seventeen breeds

which include NB18, NB4D2, KA, CSR18, etc., were found moderately tolerant (survival between 73.28 and 56.93%) whereas 16 breeds such as CSR4, 2N, 5N, etc. were in the moderately susceptible (survival between 40.58 and 56.93%) category against *B. bassiana*. The tolerance index of some breeds was 2.5 times more than that of the highly susceptible breeds.

TABLE 1. Survival percentage of different bivoltine breeds of silkworm infected by *B. bassiana*

Rank	Breeds	Status	% Survival (Mean ± SD)	TI	LT_{50} (Days)
1	CSR51	HT	85.49 ± 4.66	67.47	7.72
2	Daizo	HT	80.63 ± 5.55	64.49	6.94
3	CSR50	HT	78.69 ± 3.12	63.31	6.66
4	CSR5	HT	77.05 ± 3.84	62.31	6.22
5	MBN2	HT	74.47 ± 3.01	60.73	6.19
6	CSR8(SL)	HT	73.60 ± 2.48	60.20	5.97
7	NB4D2	MT	73.03 ± 3.84	59.85	5.92
8	A210	MT	71.97 ± 2.24	59.20	5.94
9	CSR16	MT	71.80 ± 3.22	59.09	5.80
10	CSR18	MT	71.43 ± 3.54	58.87	6.10
11	5 HT	MT	71.28 ± 2.90	58.78	5.94
12	CSR2DR	MT	70.68 ± 2.14	58.41	5.89
13	A208	MT	70.05 ± 3.42	58.02	6.02
14	ND7	MT	68.59 ± 3.85	57.13	5.77
15	SBNP4	MT	67.91 ± 6.01	56.72	5.93
16	SD7	MT	67.15 ± 3.83	56.25	5.74
17	CSR21DR	MT	66.18 ± 3.06	55.65	5.76
18	KA	MT	65.29 ± 3.32	55.11	5.80
19	8 HT	MT	63.20 ± 2.46	53.83	5.73
20	SD12	MT	61.84 ± 3.15	53.00	5.61
21	RD1	MT	60.36 ± 3.42	52.10	5.62
22	SBNP7	MT	59.98 ± 3.44	51.86	5.65
23	NB18	MT	56.93 ± 3.17	50.00	5.57
24	CSR4DR	MS	55.60 ± 4.07	49.19	5.57
25	JPN 8	MS	54.27 ± 4.72	48.37	5.52
26	ND5	MS	53.77 ± 3.17	48.07	5.51
27	CSR5DR	MS	53.26 ± 3.10	47.75	5.53
28	A	MS	53.01 ± 1.53	47.60	5.57
29	B 217	MS	52.55 ± 2.46	47.32	5.45
30	5N	MS	51.57 ± 3.50	46.72	5.54
31	CSR4	MS	50.50 ± 4.05	46.06	5.38
32	NB7	MS	49.67 ± 3.36	45.56	5.38
33	SL7(SL)	MS	46.40 ± 3.94	43.56	5.32

continued...

Table 1 continued...

Rank	Breeds	Status	% Survival (Mean ± SD)	TI	LT_{50} (Days)
34	CSR28DR	MS	45.45 ± 3.68	42.98	5.25
35	SBNP1	MS	44.90 ± 3.99	42.64	5.26
36	2N	MS	43.87 ± 2.61	42.01	5.24
37	SBNP6	MS	43.08 ± 3.36	41.53	5.22
38	CSR2 (SL)	MS	41.53 ± 3.39	40.58	5.14
39	61N	MS	41.01 ± 3.24	40.26	5.18
40	CSR17	HS	39.62 ± 4.01	39.41	5.12
41	A69	HS	39.62 ± 3.98	39.41	5.16
42	SBNP12	HS	30.40 ± 2.68	33.77	5.02
43	B62	HS	26.96 ± 4.35	31.67	5.01
44	CSR19	HS	21.38 ± 3.47	28.26	4.96
45	CSR2	HS	15.85 ± 4.49	24.88	4.89
		Mean	56.93 ± 16.35		

HT, Highly tolerant; MT, Moderately tolerant; MS, Moderately susceptible; HS, Highly susceptible

The LC_{50}, LC_{90}, LT_{50} and LT_{90} values for the III instar larvae of the two highly tolerant (CSR51 and Diazo), two highly susceptible (CSR19 and CSR2) and one moderately tolerant (NB18) breeds are given in Table 2. The LC_{50} and LC_{90} values for highly tolerant breeds CSR51 and Diazo were $10^{4.4050}$ and $10^{4.3471}$ and $10^{5.1010}$ and $10^{5.0415}$, respectively. It was $10^{4.0937}$ and $10^{4.7160}$ for moderately tolerant breed NB18. For highly susceptible breeds CSR19 and CSR2 the LC_{50} value was $10^{3.2285}$ and $10^{4.1938}$ and LC_{90} value was $10^{3.0416}$ and $10^{4.0680}$, respectively. The median lethal time of highly tolerant breed CSR51 was 7.32 days where as in the susceptible breed CSR2, it was 4.13 days. Days to kill 90% population in CSR51 and Diazo were 9.59 and 8.88 days, respectively while in CSR19 it was 5.22 and in CSR2, 5.21 days. It took 4.96 days to kill 50% and 6.41 days to cause 90% mortality for *B. bassiana* in NB18 breed.

DISCUSSION

For the management of silkworm diseases, avoidance of extreme susceptibility of silkworm to pathogens by using disease resistant/tolerant breeds is a most attractive approach. To develop disease resistant/tolerant breeds, the genetic mechanism underlying it should be properly understood so as to effectively transgress the tolerance in to productive breeds (Sen *et al.*, 1997). Insects in general are observed to respond differentially to infection by microbial pathogens (Briese, 1981) and such differences are genetically determined and have been studied extensively in silkworm to develop disease resistant breeds (Tanada and Kaya, 1993). The susceptibility of silkworm to different pathogens is a polygenic character (Aratake, 1973a,b) with the exception to BmDNV (Watanabe and Maeda, 1981).

TABLE 2. Lethal concentration of *B. bassiana* and lethal time to the selected bivoltine breeds of silkworm

Breed	LC_{50} (Conidia/ml)	LC_{90} (Conidia/ml)	LT_{50} (Days)	LT_{50} (Days)
CSR51	$1 \times 10^{4.4050}$	$1 \times 10^{5.1010}$	7.32	9.59
Daizo	$1 \times 10^{4.3471}$	$1 \times 10^{5.0415}$	6.89	8.88
NB 18	$1 \times 10^{4.0937}$	$1 \times 10^{4.7160}$	4.96	6.41
CSR19	$1 \times 10^{3.2285}$	$1 \times 10^{4.1938}$	4.20	5.22
CSR2	$1 \times 10^{3.0416}$	$1 \times 10^{4.0680}$	4.13	5.21

The present study indicated wide variation in the mortality, survival, lethal time and lethal concentration in the different bivoltine breeds after challenging with uniform dose of *B. bassiana*. Among the 45 bivoltine breeds screened, only in 4 breeds, the larvae survived after 10 days post inoculation. It is clear that, except in a few, larvae in almost all the breeds succumbed to the infection over a period of time. From the variability observed among and even within the stocks as evident form the CV, it is clear that different genetic mechanisms of these races may be responsible for their differential tolerance/susceptibility to *B. bassiana*. Large difference exists among various strains of silkworms in their susceptibility to infections of different disease causing pathogens like BmNPV, BmCPV, BmIFV, *B. bassiana*, *Aspergillus sp.* and *N. bombycis* (Aruga and Watanabe, 1964; Watanabe, 1966; Watanabe and Maeda, 1978, 1981; Baig *et al.*, 1991; Nataraju, 1995). This difference in response influences the initiation and development of epizootics of infectious diseases (Watanabe, 1987).

For finding the tolerance level of the breeds against *B. bassiana*, the total mortality could not be taken into consideration because except in a few, the larvae in most of the breeds succumbed to the infection when kept for longer durations after inoculation. Hence, mortality after five days of inoculation, the median lethal time (LT_{50}) and day to mortality which gave a distinct demarcation between the breeds were considered. This indicated significant difference between the breeds. Studies by Samson *et al.* (1979) also indicated that even though the breeds screened against *B. bassiana* succumbed to the infection there was marked difference in the time of mortality in KA and HM II × KA.

In the present study, no breeds were found resistant to *B. bassiana* as evident from the mortality, but horizontal resistance as indicated by the higher LT_{50} value as well as higher LC_{50} values of certain breeds was evident. Earlier studies in India also indicated variability in the tolerance level of breeds against the fungal pathogen *B. bassiana*. Narasimhanna *et al.* (1976) screened some multivoltine breeds against *B. bassiana* and found that Moria followed by NS4 and Nistid as relatively tolerant. Reddy (1978) found that the multivoltine breed, pure Mysore offers more resistance when compared to the bivoltine J122. Studies by Raghavaiah and Jayaramaiah (1989, 1990) also indicated the higher susceptibility of a bivoltine breed NB18 to *B. bassiana* when compared to that of C. Nichi breed. Jhansi lakshmi *et al.* (2005) showed that a

bivoltine race, APS8 as highly susceptible compared to the other races when screened against *B. bassiana*.

The variability observed among the different breeds indicated that there may be different genetic mechanisms responsible for their tolerance to *B. bassiana*. The results of the study indicated that the breeds differ in their tolerance level towards *B. bassiana* and quite a few breeds are highly tolerant suggesting ample possibilities for utilizing them in the breeding programs. The variation in the susceptibility in silkworm breeds to *B. bassiana* is genetically determined. There are two major genes responsible for muscardine infection in silkworm. One is 'mus' gene located in the 11th chromosome and the other is 'cal' gene located in the 7th chromosome (Shimada, 1999). Besides these main genes muscardine susceptibility may also be related to several polygenes. Aratake (1961) stated that susceptibility to muscardine disease varies among the different silkworm breeds. The present study establishes that tolerant breeds do exist among bivoltine breeds along with susceptible and moderately tolerant ones and there is ample scope for utilizing these *B. bassiana* tolerant breeds in developing resistant/tolerant breeds with superior economic characters.

ACKNOWLEDGEMENTS

The first author expresses gratitude to the Director, Central Sericultural Research and Training Institute, Mysore for providing laboratory facilities and is thankful to colleagues in Silkworm Pathology section of the Institute. We grateful to Dr. N. Sureshkumar, Scientist-C, for providing the silkworm breeds and Mr. A. K. Palit, Assistant Director (Economics) for analyzing the data.

REFERENCES

Aratake, Y. (1961) Genetical analysis of the infection with muscardines of *Bombyx mori* L. I. Infection with the white muscardine. *Bulletin of Sericulture Experimental Station (Tokyo)* 17(1): 155–170.

Aratake, Y. (1973a) Strain difference of the silkworm, *Bombyx mori* L, in the resistance to a nuclear polyhedrosis virus. *Journal of Sericulture Sciences Japan* 42(3): 230–238.

Aratake, Y. (1973b) Difference in the resistance to infectious flacherie virus between the strains of the silkworm, *Bombyx mori* L. *Sansi-Kenkyu* 86(1): 48–57.

Aruga, H. and Watanabe, H. (1964) Resistance to *per os* infection with cytoplasmic polyhedrosis virus in the silkworm, *Bombyx mori* (Linnaeus). *Journal of Insect Pathology* 6: 387–394.

Baig, M., Sharma, S. D., Balavenkatasubbaiah, M., Samson, M. V., Sasidharan, T. O. and Noamani, M. K. R. (1991) Relative susceptibility of different races of silkworm, *Bombyx mori* L. to nuclear polyhedrosis under natural and induced conditions. *Sericologia* 31(3): 417–420.

Briese, D. T. (1981) Resistance of insect species to microbial pathogens. In: *Pathogenesis of Invertebrate Microbial Diseases*, Davidson, E. W. (Ed). Allanheld-Osmun, Totowa, New Jersey, USA, 511–545.

Chinnaswamy, K. P. and Devaiah, M. C. (1984) Susceptibility of different races of silkworm, *Bombyx mori* L. to aspergillosis caused by *Aspergillus tamarii* Kita. *Sericologia* 24(4): 513–517.

Finney, D. J. (1971) *Probit Analysis*, 3rd edn, S. Chand and Co., New delhi, p. 333.

Jhansi lakshmi, V. V. N. S., Kaiser, J., Venkaiah, K., Bharathi, D. and Satyakumar, D. V. R. (2005) Differential susceptibility of silkworm, *Bombyx mori* L. races to white muscardine disease caused by *Beauveria bassiana* (Bals.) Vuill. *Entomon* 30(1): 13–18.

Mano, Y., Nirmalkumar, S., Basavaraja, H. K., Malreddy, N. and Datta, R. K. (1998) Combined trait selection index for silk yield improvement in *Bombyx mori* L. In: *Proceedings of National Workshop on Silkworm Breeding, March 1994*, Department of Sericulture, University of Mysore, Oxford and IBH, New Delhi, 278–284.

Narasimhanna, M. N., Samson, M. V. and Baig, M. (1976) Studies on the control of white muscardine disease of silkworms. In: *Annual Report, 1975-1976*, Central Sericultural Research and Training Institute, Mysore, India, 106–112.

Nataraju, B. (1995) Studies on diagnosis and prevention of nuclear polyhedrosis in silkworm, *Bombyx mori* L, *Ph.D. Thesis*, University of Mysore, Mysore, India.

Raghavaiah, G. and Jayaramaiah, M. (1989) Lethal concentration of white muscardine fungus *Beauveria bassiana* (Bals.) Vuill. to different races of mulberry silkworm. *Indian Journal of Sericulture* 28(1): 94–96.

Raghavaiah, G. and Jayaramaiah, M. (1990) Susceptibility of some races of the silkworm *Bombyx mori* to white muscardine disease. *Indian Journal of Sericulture* 29(2): 304–307.

Sen, R., Patnaik, A. K., Maheshwari, M. and Datta, R. K. (1997) Susceptibility status of the silkworm (*Bombyx mori*) germplasm stocks in India to *Bombyx mori* nuclear polyhedrosis virus. *Indian Journal of Sericulture* 31(1): 51–54.

Samson, M. V., Baig, M. and Nataraju, B. (1979) Studies on white muscardine disease of silkworm. In: *Annual Report, 1978-1979*, Central Sericultural Research and Training Institute, Mysore, India, 63–64.

Selvakumar, T., Nataraju, B., Balavenkatasubbaiah, M., Sivaprasad, V., Baig, M., Virendrakumar,, Sharma, S. D., Thiagarajan, V. and Datta, R. K. (2002) A report on the prevalence of silkworm diseases and estimated crop loss. In: *Advances in Indian Sericulture Research (Proceedings of National Conference on Strategies for Sericulture Research and Development, November, 16–18, 2000*, Dandin, S. B. and Gupta, V. P. (Eds). Central Sericultural Research and Training Institute, Mysore, India, 354–357.

Shimada, T. (1999) Genetic mapping of virus resistance in *Bombyx mori* and *Bombyx mandarina*. *Riken Review* 22: 68–71.

Tanada, Y. and Kaya, H. K. (1993) *Insect Pathology*, Academic Press, Inc., New York, p. 666.

Reddy, V. M. R. (1978) Studies on the white muscardine disease of silkworm, *Bombyx mori*, L, *M.Sc. (Agri) Thesis*, University of Agriculture Sciences, Bangalore, India, p. 93.

Watanabe, H. (1966) Genetic resistance to *per oral* infection with the cytoplasmic polyhedrosis virus in the silkworm, *Bombyx mori* L. *Journal of Sericulture Sciences Japan* 35(1): 27–31.

Watanabe, H. (1987) The host population. In: *Epizootiology of Insect Diseases*, Fuxa, J. R. and Tanada, Y. (Eds). Willey-Inter Science, New York, USA.

Watanabe, H. and Maeda, S. (1978) Genetic resistance to *per oral* infection with a densonucleosis virus in the silkworm, *Bombyx mori*. *Journal of Sericulture Sciences Japan* 47(3): 209–214.

Watanabe, H. and Maeda, S. (1981) Genetically determined non susceptibility of the silkworm, *Bombyx mori* to infection with a densonucleosis virus (densovirus). *Journal of Invertebrate Pathology* 38(3): 370–373.

(Received 10 December 2008; accepted 15 December 2008)

ENTOMON 33(4): 267–273 (2008)
Article No. ent.33407

Functional response of *Coccinella transversalis* L. (Coleoptera: Coccinellidae) feeding on mustard aphid, *Lipaphis erysimi* (Kaltenback)

P. K. Sarker, J. A. Begum and B. C. Das*

Department of Zoology, University of Rajshahi, Rajshahi 6205, Bangladesh
Email: bcdzool@yahoo.com

ABSTRACT: Experiments were conducted to study the functional response of *Coccinella transversalis* L. (Coleoptera: Coccinellidae) feeding on mustard aphid, *Lipaphis erysimi* (Kaltenback) (Homoptera: Aphididiae) under laboratory conditions. Six densities of prey (*L. erysimi*) were evaluated. *C. transversalis* fits well with the Type-II functional response model for all life stages based on maximum value of coefficient of determination (r^2). The consumption rate and percentages of prey consumption were positively and negatively correlated with prey density, respectively. Fourth instar larvae consumed highest number of aphids than other instars and the adult females consumed more aphids than adult males. The handling time of *C. transversalis* decreased with the increase of prey densities. The handling time of adult females was shorter than that of adult males.

KEYWORDS: functional response, *Coccinella transversalis*, *Lipaphis erysimi*

INTRODUCTION

Functional response of a predator is a key factor regulating population dynamics of predator–prey systems (Mandour *et al.*, 2006). Determining the effects of predations on prey populations is most commonly done through the analysis of functional and numerical responses (Huffaker and Messenger, 1976). The functional response defines the rate of prey consumption, by a given number or density of predators, as a function of prey density (Holling, 1959b) and therefore, can predict the maximum number of prey that can be consumed by a given predator per day. Thus the number of prey attacked can be used to help predict predator development, survival and reproduction (Oaten and Murdoch, 1975). Early functional response research was conducted by Holling (1959a,b), who formulated the mathematical models (Type I, Type II and Type III) to describe predatory responses that were influenced by changes in predator behaviour.

*Corresponding author

Lipaphis erysimi (Kaltenbach) is one of the serious and destructive aphid pests of a variety of crops (Chattopadhyay *et al.*, 2005; Ansary *et al.*, 2007) distributed worldwide on *Brassica* crops (Blackman and Eastop, 1984; Yue and Liu, 2000).

Coccinella transversalis L. frequently occurs as a key predator of *L. erysimi* and is very effective in regulating pest population (Agarwala and Bhattacharya, 1999; Das, 1994, 2002).

A number of workers studied the functional response of different coccinellid predators on different aphid pests (Holling, 1959a; Hassell, 1978; Mandour *et al.*, 2006). However, information on levels of predation of different life stages of *C. transversalis*; determination of model, which describes best response of *C. transversalis*; and efficacy of *C. transversalis* against *L. erysimi* at different densities are still lacking and hence the present studies were carried out.

MATERIALS AND METHODS

Predator and prey

Adults of *C. transversalis* were collected from the mustard fields in Rajshahi University, Bangladesh and reared in petridish (9 cm dia) under the laboratory temperature, 20 ± 2 °C and relative humidity, 79 ± 10 per cent, adopting standard rearing procedures. The experiment was started by the first instar larvae of *C. transversalis*. Regular supply of *L. erysimi* was ensured by maintaining stock culture on mustard plants planted in tubs at 15 days interval and maintained in field. *L. erysimi* colonies were started from parthenogenetic apterous adults collected from nearby mustard field.

Experimental design and data collection

Functional response assays were conducted with the predator, *C. transversalis* and prey, *L. erysimi* in petridish (6 cm dia). The larvae/adults were starved for 24 h before the onset of experiment. Predation was assessed by placing a single larva/adult in a petridish containing small size leaves and pods. To avoid drying up of food a water-saturated cotton ball was placed inside at the bottom of each petridish.

Since predation potential of the larvae increase with moulting, prey densities were altered to ensure that there was no shortfall in the availability of food. Six densities of prey (Table 1) were evaluated. After 24 h of predation, all dead and living aphids were recorded. Five replications were maintained for each treatment. Controls were also maintained to determine the level of cannibalism and natural mortality and necessary adjustments were made in the mortality data.

Data analysis

The response of *C. transversalis* to the varying densities of the prey was assessed with mathematical models (Type I, II (Holling, 1959a,b) and Type III (Hassell *et al.*, 1977)). The coefficients of determination (r^2 values) were calculated by using a general

regression procedure (SPSS, 2005). Analysis of variance (ANOVA) was carried out to test the significant difference in predation of *C. transversalis*. Comparison of means was with Duncan's Multiple Range Test (DMRT). Handling time was time taken by *C. transversalis* for handling each prey killed.

RESULTS AND DISCUSSION

Predatory response of *C. transversalis* fits best with the Type II functional response model for all life stages based on highest value of coefficient of determination ($r^2 = 0.999878$–0.999997). The response was also close to the Type III model ($r^2 = 0.991958$–0.999576). The percentage of prey consumption by each predatory stage is negatively correlated with prey densities, whereas the consumption rate increased with the increase of prey density (Table 1). The r^2 value was highest (0.9542) for second instar and lowest (0.3011) for first instar larvae of *C. transversalis*. The rate of prey consumption declined with the increase of prey density for predatory stages, suggesting that these stages exhibit a Type II functional response model. Fourth instar larvae consumed highest number of aphids than other instars and the adult females consumed more aphids than the adult males (Table 1). The handling time of *C. transversalis* decreased with the increase of prey densities offered for all cases (Table 2). The mean handling time also decreased with the increase of life stages and the handling time of adult females was shorter than that of adult males. The functional response of *C. transversalis* to different prey densities of *L. erysimi* was similar to those of other coccinellid predators (Srivastava and Srivastava, 2003; Omkar and Pervez, 2004; Isikber, 2005; Pervez and Omkar, 2005; Mandour *et al.*, 2006) etc. Most of functional response trials resulted in a strong fit with curvilinear Type II and significantly very close with Type III model, thus allowing for interpretation as either Type II or Type III.

The present result shows that the prey consumption by the predatory stages of the beetle was directly, and the percentage of prey consumption inversely proportional to the prey density. Prey handling time decreased with increase of prey density. The predatory efficiency of the predator was directly proportional to the prey density, indicating a Holling Type II functional response.

Kumar *et al.* (1999) and Srivastava and Srivastava (2003) found that the functional response of the grub of *C. septempunctata* on *L. erysimi* was of Holling Type II model. They also found that prey consumption increased significantly with the increase of prey density and the percentage of prey consumption declined. Xia *et al.* (2003) described the models of the functional responses of the larval and adult stages of *C. septempunctata* toward mixed stage populations of *A. gossypii* in cotton and found the model suitable for calculating predation rates of *C. septempunctata* on *A. gossypii* under field conditions. Pervez and Omkar (2005) evaluated Type II response model determined by a logistic regression model and found that *C. sexmaculata* responded maximally, followed by *C. transversalis* and *P. dissecta*, in terms of consumption of the aphids, *A. craccivora* and *M. persicae*. The differences in handling time was found

TABLE 1. Prey consumed by different instars of *C. transversalis* on different densities of *L. erysimi* population

First instar		Second instar		Third instar		Fourth instar		Adult		
									Male	Female
Density of prey	Prey consumed (Mean)	Density of prey	Prey consumed (Mean)	Density of prey	Prey consumed (Mean)	Density of prey	Prey consumed (Mean)	Density of prey	Prey consumed (Mean)	Prey consumed (Mean)
10	5.4e	20	17.0c	25	21.0d	30	21.0e	50	40.6e	45.4e
20	10.4d	40	28.8b	50	31.4c	60	30.0de	75	50.0d	57.0d
30	13.2d	60	35.4b	75	37.6c	90	38.8cd	100	50.0d	59.6d
40	19.4c	80	45.8a	100	45.8b	120	52.4ab	125	56.4c	69.8c
50	23.2b	100	44.4a	125	51.4ab	150	47.4bc	150	61.0b	77.0b
60	29.4a	120	50.2a	150	56.4a	180	60.6a	200	68.0a	90.2a
'p' value	0.00		0.00		0.00		0.00		0.00	0.00

Means followed by the same letter did not differ significantly at $P < 0.01$ by DMRT.

TABLE 2. Handling time taken by the predator, *C. transversalis* at different densities of *L. erysimi* population

1st instar		2nd instar		3rd instar		4th instar		Adult		
									Male	Female
Density	Handling time	Density	Handling time	Density	Handling time	Density	Handling time	Density	Handling time	Handling time
10	4.44	20	1.41	25	1.14	30	1.14	50	0.59	0.53
20	2.31	40	0.83	50	0.76	60	0.80	75	0.48	0.42
30	1.82	60	0.68	75	0.64	90	0.62	100	0.48	0.40
40	1.24	80	0.52	100	0.52	120	0.46	125	0.43	0.34
50	1.03	100	0.54	125	0.47	150	0.51	150	0.39	0.31
60	0.82	120	0.48	150	0.43	180	0.40	200	0.35	0.27
Mean	1.94	–	0.74	–	0.66	–	0.66	–	0.45	0.38

significant within and between the predatory species on both prey species indicating that predators respond differently to prey species.

The results of the present experiment indicate that *C. transversalis* fits well with the Type II model of Holling's disc equation and would be an effective coccinellid predators of mustard aphid, *L. erysimi* in Bangladesh.

ACKNOWLEDGEMENTS

Thanks are due to the Chairman, Department of Zoology, Rajshahi University, Rajshahi 6205, Bangladesh for providing laboratory facilities and to the Ministry of Science and Information & Communication Technology, Government of the People's Republic of Bangladesh for financial support.

REFERENCES

Agarwala, B. K. and Bhattacharya, S. (1999) Effective biocontrol agents and their use in IPM strategy of the mustard aphid. In: *IPM System in Agriculture*, Upadhyay, R. K., Mukerji, K. G. and Rajak, R. L. (Eds). Aditya Books Pvt.Ltd., New delhi, 77–89.

Ansary, M. S., Hussain, B. and Qazi, N. A. (2007) Influence of abiotic environment on the population dynamics of mustard aphid, *Lipaphis erysimi* (Kalt.) on *Brassica* germplasm. *Journal of Biological Science* 7(6): 993–996.

Blackman, R. L. and Eastop, V. F. (1984) Aphids on the World's Crops. In: *An Identification and Information Guide*, John Wiley and Sons, Chichester, New York, Brisbane, Toronto, Singapore, 1–466.

Chattopadhyay, C., Agrawal, R., Kumar, A., Singh, Y. P., Roy, S. K., Khan, S. A., Bhar, L. M., Chakravarthy, N. V. K., Srivastava, A., Patel, B. S., Srivastava, B., Singh, C. P. and Mehta, S. C. (2005) Forecasting of *Lipaphis erysimi* on oilseed Brassicas in India—a case study. *Crop Protection* 24: 1042–1053.

Das, B. C. (1994) Aphids (Homoptera: Aphididae) and their natural enemies in Bangladesh. *Environment and Ecology* 12(4): 795–801.

Das, B. C. (2002) Ecology and diversity of agricultural crop infesting aphids (Homoptera: Aphididae) in Bangladesh. *Journal of Aphidology* 16: 51–57.

Hassell, M. P. (1978) *The Dynamics of Arthropod Predator Prey Systems Monographs in Population Biology. 13*, Princeton University Press, Princeton, NJ, p. 237.

Hassell, M. P., Lawton, J. H. and Beddington, J. R. (1977) Sigmoid functional responses by invertebrate predators and parasitoids. *Journal of Animal Ecology* 46: 249–262.

Holling, C. S. (1959a) The components of predation as revealed by a study of small mammal predation of European pine sawfly. *Canadian Entomologist* 91: 293–320.

Holling, C. S. (1959b) Some characteristics of simple types of predation and parasitism. *Canadian Entomologist* 91: 385–398.

Huffaker, C. B. and Messenger, P. S. (1976) *Theory and Practice of Biological Control*, Academic Press, New York.

Isikber, A. A. (2005) Functional response of two coccinellid predators, *Scymnus levaillanti* and *Cycloneda sanguinea*, to the Cotton Aphid, *Aphis gossypii*. *Turkish Journal of Agriculture and Forestry* 29: 347–355.

Kumar, A., Kumar, N., Siddiqui, A. and Tripathi, C. P. M. (1999) Prey–predator relationship between *Lipaphis erysimi* Kalt. (Hom., Aphididae) and *Coccinella septempunctata* L. (Col., Coccinellidae). II. Effect of host plants on the functional response of the predator. *Journal of Applied Entomology* 123: 591–601.

Mandour, N. S., El-Basha, N. A. and Liu, T. X. (2006) Functional response of the ladybird, *Cydonia vicina nilotica* to cowpea aphid, *Aphis craccivora* in the laboratory. *Insect Science* 13: 49–54.

Oaten, A. and Murdoch, W. W. (1975) Functional response and stability in predator–prey systems. *The American Naturalist* 109: 289–298.

Omkar, and Pervez, A. (2004) Functional and numerical responses of *Propylea dissecta* (Col., Coccinellidae). *Journal of Applied Entomology* 128: 140–146.

Pervez, A. and Omkar, (2005) Functional responses of coccinellid predators: an illustration of logistic approach. *Journal of Insect Science* 5(5): p. 6.

Srivastava, O. and Srivastava, S. (2003) Functional response of the sevenspotted lady beetle, *Coccinella septempunctata* Linnaeus on the mustard aphid, *Lipaphis erysimi* (Kaltenbach). *Insect Science and Its Application* 23(2): 149–152.

Xia, J. Y., Rabbinge, R. and Van Der Werf, W. (2003) Multistage functional responses in a Ladybeetle-Aphid System: Scaling up from the laboratory to the field. *Environmental Entomology* 32(1): 151–162.

Yue, B. and Liu, T. (2000) Host selection, development, survival, and reproduction of turnip aphid (Homoptera: Aphididae) on green and red cabbage varieties. *Journal of Economic Entomology* 93(4): 1308–1314.

(Received 26 August 2008; accepted 15 November 2008)

ENTOMON **33(4)**: 275–276 (2008)
Short Communication No. ent.33408

Occurrence of *Aedes (Stegomyia) krombeini* (Diptera: Culicidae) in Assam, India

D. R. Bhattacharyya, Anil Prakash, P. K. Mohapatra, D. K. Sarma and J. Mahanta

Regional Medical Research Centre, NE Region, Indian Council of Medical Research, Post Box No. 105, Dibrugarh 786 001, Assam, India
Email: icmrrcdi@hub.nic.in; anilprakashin@yahoo.co.in

ABSTRACT: This communication reports the occurrence of *Aedes (Stegomyia) krombeini* Huang in Pobitora wild life sanctuary, Assam, India.

KEYWORDS: *Aedes krombeini*, Assam, new distribution, Pobitora wildlife sanctuary

Aedes krombeini Huang belonging to the sub-group *scutellaris* and subgenus *Stegomyia*, was first described from Sri Lanka by Huang (1975a). He also reported the species to be very common in Sri Lanka which probably remained undetected as it was mistaken for another common species *Ae. albopictus* coming under *Scutellaris* group but in *albopictus* sub-group. Tewari *et al.* (1987) reported the occurrence of *Ae. krombeini* for the first time from India; in the hill ranges of Tamil Nadu, and observed that probably due to its close resemblance with the widely distributed *Ae. albopictus*, this species may be remaining undetected elsewhere in India.

During May 2007 we collected mosquito immatures from tree holes in Pobitora wildlife sanctuary, Assam and link reared them individually in the laboratory resulting in the emergence of 10 adults. Of these, four adults were identified as *Ae. krombeini* and six as *Ae. albopictus*. Identity of *Ae. krombeini* was confirmed based on adult morphological features which matched perfectly with the description given by Huang (1975a). Three adult specimens (A14-7, A14-8, A14-10) along with their associated larval (L14-7, L14-8, L14-10) and pupal exuviae (p14-7, p14-8, p14-10) are deposited in the museum of RMRC, Dibrugarh, Assam, India.

The observed distribution of *Ae. krombeini* at the north and south ends of India alone strengthen the suggestion of Tewari *et al.* (1987) that the species may be available all over India and now remain undetected due to its resemblance with *Ae. albopictus* and consequent confusion in identification. *Ae. krombeini* as well as other species under *scutellaris* sub-group can be differentiated from *albopictus* sub-group by the presence of a complete, well-developed supra-alar white line of broad flat scales over the wing

FIGURE 1. Arrow shows the supra-alar white line over the wing root of *Ae. krombeini*.

root extending to the scutellum in the former (figure 1). Dengue virus, generally prevalent in urban settings, has been isolated from *Ae. albopictus* in rural areas of Tamil Nadu too (Tewari *et al.*, 2004).

Ae. krombeini is reported to feed on human blood (Huang, 1975a). Moreover, cell line of *Ae. krombeini* is found to be susceptible to some arboviruses (Pant *et al.*, 1992). Species like *Ae. (Stg.) polynesiensis* and *Ae. (Stg.) pseudoscutellaris* which are major vectors of sub-periodic filariasis in Pacific region (Huang, 1975b) and *Ae. scutellaris* a vector of dengue in New Guinea (Mackerras, 1946) come under the sub-group *scutellaris*. Detailed population survey and correct identification of mosquito species is of great medical importance.

ACKNOWLEDGEMENTS

We are grateful to Dr. Yiau-Min Huang, Department of Entomology, Smithsonian Institution, Washington D.C., USA for confirming the identification of the species.

REFERENCES

Huang, Y. M. (1975a) A new species of *Aedes* (*Stegomyia*) from Sri Lanka (Ceylon) (Diptera: Culicidae). *Mosquito Systematics* 7(4): 345–356.

Huang, Y. M. (1975b) A redescription of *Aedes (Stegomyia) pseudoscutellaris* (Theobald) with a note on the taxonomic status of *Aedes (Stegomyia) polynesiensis* Marks (Diptera : Culicidae). *Mosquito Systematics* 7(1): 87–99.

Mackerras, I. M. (1946) Transmission of dengue fever by *Aedes* (*Stegomyia*) *scutellaris* Walk in New Guinea. *Transaction of Royal Society of Tropical Medicine and Hygiene* 40: 295–312.

Tewari, S. C., Hiriyan, J. and Reuben, R. (1987) Occurrence of *Aedes* (*Stegomyia*) *krombeini* Huang (Diptera : Culicidae) in India. *Current Science* 14: 736–737.

Tewari, S. C., Thenmozhi, V., Katholi, C. R., Manavalan, R., Munirathinam, A. and Gajanana, A. (2004) Dengue vector prevalence and virus infection in a rural area in south India. *Tropical Medicine and International Health* 9(4): 499–507.

Pant, U., Sudeep, A. B. and Athawale, S. S. (1992) Susceptibility of *Aedes krombeini* cell line to some Arboviruses. *Indian Journal of Medical Research* 95(9): 239–244.

(Received 5 November 2007; accepted 30 September 2008)

ENTOMON **33(4)**: 277–282 (2008)
Short Communication No. ent.33409

On the problems in diagnostics of cotton mealybug *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae)

Asha Thomas and V. V. Ramamurthy*

Division of Entomology, Indian Agricultural Research Institute, New Delhi 110 012, India
Email: vvr3@vsnl.com/ashabio@gmail.com

ABSTRACT: Detailed studies on the mealybugs collected recently from different parts of India on cotton and other hosts revealed the abundance of *Phenacoccus solenopsis* Tinsley. These studies also revealed that there had been confusions in the identification of this species due to synonymy, misidentifications, and anomalies due to material preparation, terminology and interpretation of taxonomic characters, in particular, the multilocular disc pores and circulus. The present study through analysis of populations from all over India, and from illustrated diagnostics of the distinguishing characters at all taxonomic levels updates the taxonomic conclusions on the multilocular disc pores in the abdominal segments.

KEYWORDS: *Phenacoccus solenopsis* Tinsley, cotton, diagnostics, taxonomic characters, multilocular disc pores, circulus

Mealybugs of the family Pseudococcidae are emerging as one of the serious pest problems in the cotton growing tracts of India. Though cotton had been reported as a host for twenty-two species so far, *P. solenopsis* is the most serious. The perusal of literature reveals that there had been confusion in the species identity due to misidentifications (Gautam *et al.*, 2007; Suresh and Kavitha, 2007; Anonymous, 2008), synonymy (Abbas *et al.*, 2005) and phenotypic variations in the populations (Williams and Granara de Willink, 1992; Miller *et al.*, 2005; Hodgson *et al.*, 2008). This confusion is compounded due to anomalies in the interpretation of taxonomic characters, their terminology, and material preparation, in particular, the multilocular disc pores and circulus. Therefore, a detailed study over large samples of populations from different hosts and localities of India has become imminent. Hodgson *et al.* (2008) attempts this but it encompasses, only limited populations from India (Tamil Nadu and Punjab). The present study focuses on this lacuna through an objective analysis of populations of *P. solenopsis* over a larger range from Tamil Nadu to

*Corresponding author

Delhi, with a focus on the multilocular disc pores. Illustrations of the diagnostic characters and simplification of details had also been achieved to enable authentic species identification.

1153 specimens analysed taking into account Sulc (1944); Ferris (1950); Williams (2004), and Hardy *et al.* (2008) reveal that the salient taxonomic characters at the **family** Pseudococcidae level are, elongate to broadly oval shaped body (Figs. 1, 2), antennae with 6–9 segments (Figs. 1, 2a), three segmented labium with apicoventral setae on each side of the terminal segment (Figs. 1, 2b). Legs well developed (Figs. 1, 2c), claw with a pair of digitule and with a small tooth like projection or denticle, tarsal digitules setose or flagellate (Figs. 1, 2d), translucent pores present at least on the tibia (Figs. 1, 2e) are the characters in thorax. Tubular ducts without vestibule or oral collar tubular ducts (Figs. 1, 2f), presence of anterior and posterior pairs of ostiole (Figs. 1, 2g), anal ring at the apex with 2 rows of cells and 6 slender setae (Figs. 1, 2h), presence of trilocular pores on the dorsum and venter (Figs. 1, 2i), each cerarii with a pair of conical setae accompanied by a concentration of trilocular pores, and situated on the margins (Figs. 1, 2j), presence of circulus between III and IV segments (Figs. 1, 2k), and multilocular disc pores (Figs. 1, 2q, r, s) are distinguishing features on the abdomen. At the **subfamily** Phenacoccinae level it is defined by the nine segmented antennae (Figs. 1, 2a), all tarsal digitules setose (Figs. 1, 2d) and claw with denticle (Figs. 1, 2d). At the **generic** level it is defined by broadly oval body (Figs. 1, 2), well developed anal lobes, nine segmented antennae (Figs. 1, 2a), well developed legs (Figs. 1, 2c) with denticle on claw (Figs. 1, 2d) and tarsal digitules flagellate (Figs. 1, 2d). Translucent pores on tibia and femur (Figs. 1, 2e), oral collar tubular ducts on venter (Figs. 1, 2f), cerarii numbering 18 pairs (Figs. 1, 2), each cerarii with a pair of conical setae and trilocular pores (Figs. 1, 2j), presence of dorsal setae, which are short and lanceolate and sometimes with one or more trilocular pores near the setal collar and circulus present (Figs. 1, 2k) are the other generic characters. At **species** level *solenopsis* is distinguished by its nine segmented antennae (Figs. 1, 2a), translucent pores on the apex of the hind femur and tibia (Figs. 1, 2e), large and flaccid circulus (Figs. 1, 2k), multilocular disc pores more concentrated near the region of vulva or restricted in the segments VI to VIII (Figs. 1, 2q, r, s) and absence of quinquelocular pores.

Of these diagnostic characters difficulties exist with regard to (a) presence of multilocular disc pores in all the eight abdominal segments, from the region corresponding to the origin of hind leg to the apex of abdomen (Figs. 1, 2l–s); this conflicts with the established fact that multilocular disc pores are observed only on VI, VII and VIII segments (Figs. 1, 2q, r, s); thorough and critical examination of its variation revealed more concentration of multilocular disc pores near to the vulva or in the segments VI, VII, VIII and about 2–6 of these observed from segment I to V with tubular ducts near to marginal cerarii (Figs. 1, 2l–p). (b) Variation in the shape of circulus towards flaccid, oval, round or circular which conflicts with the notion that is always large and flaccid.

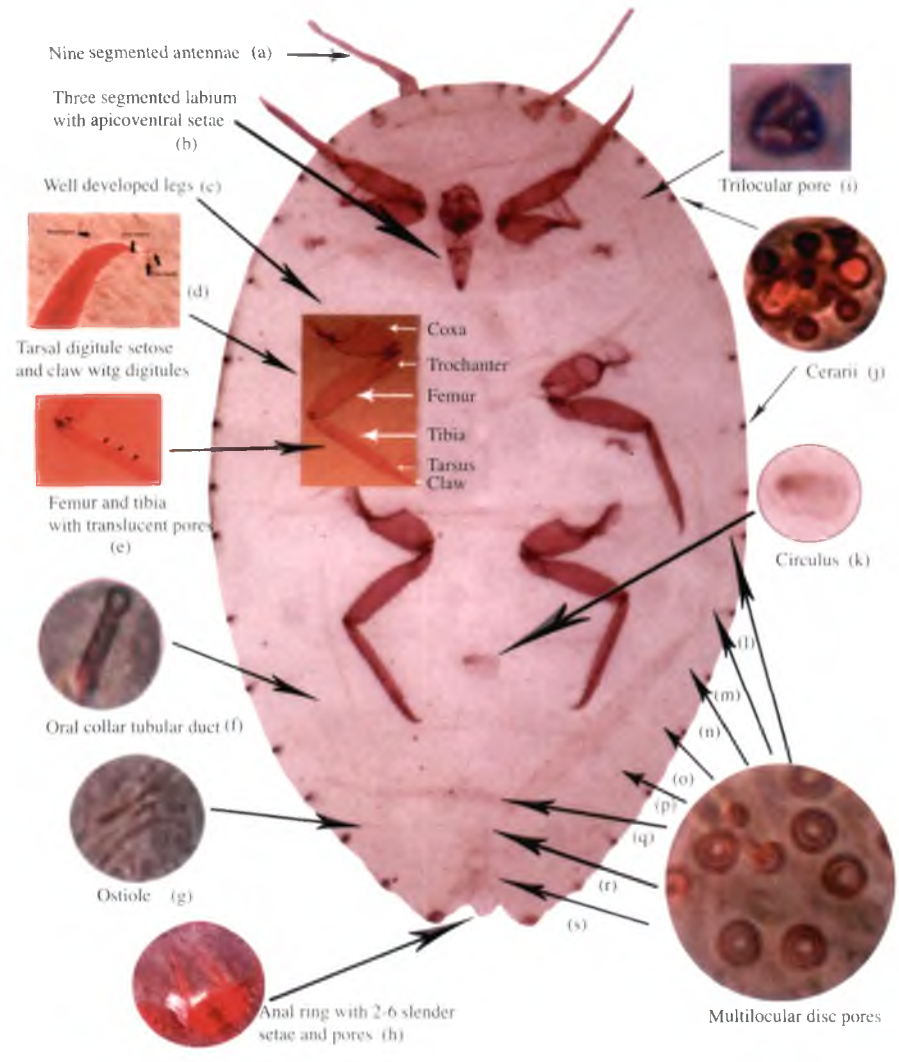


FIGURE 1. *Phenacoccus solenopsis*-key characters: a–s, a = nine segmented antennae, b = three segmented labium with apicoventral setae, c = well developed leg, d = tarsal digitule setose and claw with digitules, e = femur and tibia with translucent pores, f = oral collar tubular duct, g = ostiole, h = anal ring with 2–6 slender setae and pores, i = trilocular pore, j = cerarii, k = circulus, l to s = multilocular disc pores. (g and j from dorsal view)

Taxonomic conclusions point to intraspecific variations being very much significant in the distribution and frequency of multilocular disc pores on the abdominal segments. According to Williams (2004), McKenzie (1967) and Williams and Granara de Willink (1992) *P. solenopsis* is very similar to *P. solani*; according to these *solenopsis* differs

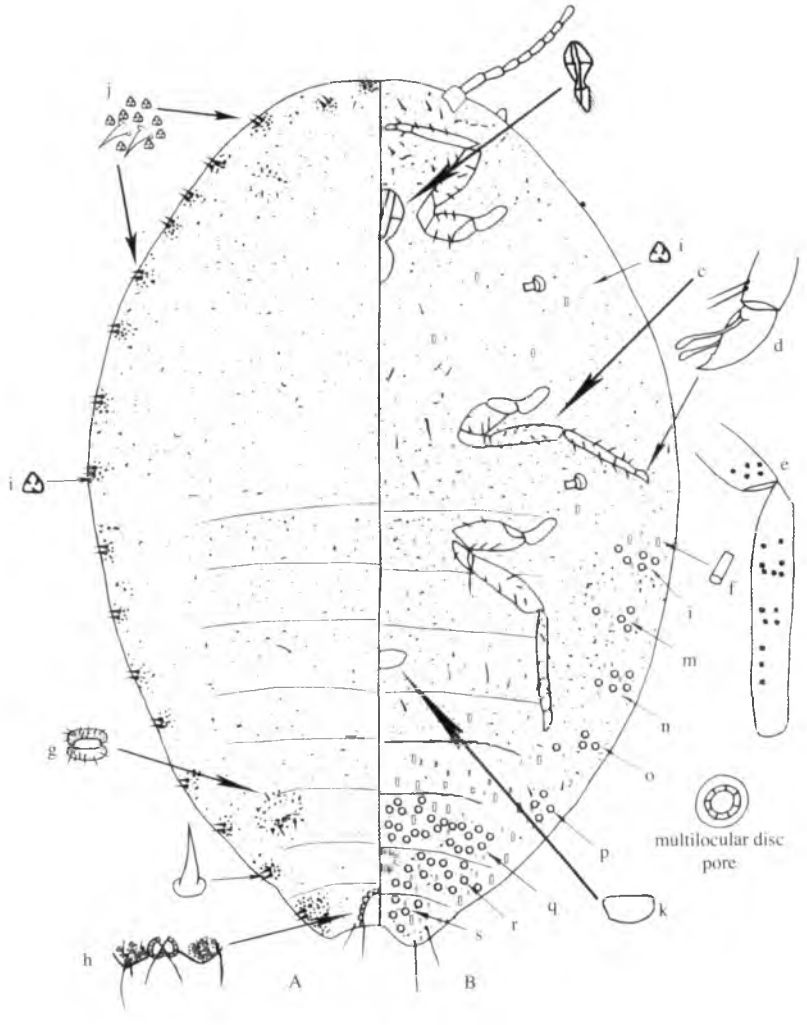


FIGURE 2. *Phenacoccus solenopsis*-key characters-diagrammatic view: A, dorsal view; B, ventral view. a = nine segmented antennae, b = three segmented labium with apicoventral setae, c = well developed leg, d = tarsal digitule setose and claw with digitules, e = femur and tibia with translucent pores, f =oral collar tubular duct, g = ostiole, h = anal ring with 2–6 slender setae and pores, i = trilocular pore, j = cerarii, k = circulus, l to s = multilocular disc pores.

in having multilocular disc pores from abdominal segments VI to VIII and a very large, flaccid circulus; *P. solani* has multilocular disc pores from abdominal segments IV to VIII and a small, oval circulus. Observation of multilocular disc pores in all the eight abdominal segments and variation in shape of circulus pose complexities in distinguishing *P. solenopsis*. Such a complexity was also noted by Gregory Evans

(pers. commn. 2008), who states "I have seen few multilocular disc pores by the cerarii all the way to A1 when examined specimens from India, Pakistan and Africa. At first we including Miller, D and Hodgson, C., considered it was a new species, however based upon further examination of series of specimens of *P. solenopsis* in the USNM collection, it appears that *P. solenopsis* sometimes has multilocular disc pores on the lateral margin up to abdominal segment 1, so we are currently considering these specimens as variants of *P. solenopsis*. Miller, D. believes that there may be a complex of closely related species that have not been differentiated morphologically to this point". Likewise Ben Dov (2005) also reported considerable intraspecific variation in the number of multilocular disc pores on segment IV, ranging from total absence to 8 pores per segment in *P. solani*. Variation in shape of circulus had also been pointed out- "in *P. solenopsis* its circulus is usually larger and more lax and becomes involved in intersegmental fold between the fourth and fifth segments. It is thus susceptible to distortion in preparations and in addition is at times laterally produced" (Ferris, 1950).

When such conflicting views on the occurrence of multilocular disc pores and shape of circulus in the Indian populations of *P. solenopsis* were being scrutinized during the present study, a simultaneous opinion by Hodgson *et al.* (2008) affirmed our supposition that these characters vary to a large extent in the populations from various parts of India warranting attention towards a careful analysis. Our observations point to the fact that one has to be cautious in distinguishing *P. solenopsis* taxonomically, especially with regard to the multilocular disc pores. With the discrepancy in the validity of the distinguishing nature of multilocular disc pores and circulus getting clarified now, and until the molecular studies are taken up to narrow down on the confusions, it will be worthwhile to take cognizance of all the distinguishing characters in a holistic plane, as illustrated now. Attention is also required towards the anomalies in the multilocular disc pores in the abdomen for authentic identification of *P. solenopsis* on cotton from India. Need to further explore the gaps in the geographical distribution, morphometrics of the phenotypic variations and molecular studies have become now imminent.

ACKNOWLEDGMENT

We are grateful to Dr.Gregory Evans, USDA-APHIS, Systematic Entomology Laboratory, Beltsville, USA for his observations on the variations in the character of multilocular disc pores which prompted this study.

REFERENCES

Abbas, G., Arif, M. J. and Saeed, S. (2005) Systematic status of a new species of the genus *Phenacoccus* Cockerell (Pseudococcidae), a serious pest of cotton, *Gossypium hirsutum* L. *Pakistan Entomologist* 27: 83–84.

Anonymous, (2008) *2007/2008 Annual report of the Central Cotton Research Institute, Multan, Pakistan Central Cotton Committee, Ministry of Food*, Agriculture and Livestock, Islamabad, Pakistan.

Ben Dov, Y. (2005) The solanum mealybug, *Phenacoccus solani* Ferris (Hemiptera: Pseudococcidae) extends its distribution range in the Mediterranean basin. *Phytoparasitica* 33(1): 15–16.

Ferris, G. F. (1950) *Atlas of the scale insects of North America, V, The Pseudococcidae (Part 1)*, Standard University Press, California, p. 278.

Gautam, R. D., Saxena, U., Gautam, S., Khan, M. A. and Gautam, C. P. N. (2007) Studies on solanum mealybug, *Phenacoccus solani* Ferris (Hemiptera: Pseudococcidae), its parasitoid and predator complex, reproductive potential and utilization as laboratory prey for rearing the ladybird and green lacewing predators. *Journal of Entomological Research* 31(3): 133–137.

Gregory, A. E. (2008) *USDA-APHIS*, Systematic Entomology Lab, Beltsville, Personal communication

Hardy, N. B., Gullan, P. J. and Hodgson, C. J. (2008) A subfamily level classification of mealybugs (Hemiptera: Pseudococcidae) based on integrated molecular and morphological data. *Systematic Entomology* 33: 51–71.

Hodgson, C., Abbas, G., Arif, M. J., Saeed, S. and Karkar, H. (2008) *Phenacoccus solenopsis* Tinsley (Sternorrhyncha: Coccoidea: Pseudococcidae), an invasive mealybug damaging cotton in Pakistan and India, with a discussion on seasonal morphological variation. *Zootaxa* 1913: 1–35.

McKenzie, H. (1967) *Mealybugs of California with Taxonomy, Biology and Control of North American Species (Homoptera: Coccoidea: Pseudococcidae)*, University of California Press, Berkeley, p. 524.

Miller, G. L., Miller, G. L., Hodges, G. S. and Davidson, J. A. (2005) Introduced scale insects (Hemiptera: Coccoidea) of the United States and their impact on U.S. agriculture. *Proceedings of the Entomological Society of Washington* 107: 123–158.

Sulc, K. (1944) Antoninella n.gen. synon. (Coccoidea, Homoptera). *Vestnik Ceskoslovenske Zoologicke Spolecnosti (Acta Societatis Zoologicae Bohemoslovenica)* 9: 148–170.

Suresh, S. and Kavitha, P. C. (2007) Seasonal incidence of economically important coccid pests of Tamil Nadu. In: *Proceedings of the XI International Symposium on Scale Insect Studies*, Oeiras, Portugal, 24-27 September 2007, poster No. 22

Williams, D. J. (2004) *Mealybugs of Southern Asia*, Southdene Sdn, Bhd, Kuala Lumpur, Malaysia, p. 896.

Williams, D. J. and Granara de Willink, M. C. (1992) *Mealybugs of Central and South America*, CAB International, Wallingford, UK, p. 635.

(Received 10 December 2008; accepted 20 December 2008)

ENTOMON 33(4): 283–284 (2008)
Short Communication No. ent.33410

Influence of temperature on the total protein content in the silk gland of multivoltine mulberry silkworm, *Bombyx mori* Linn.

V. B. Upadhyay, S. K. Gupta*, K. P. Gaur, C. Srivastava and S. Prasad

Silkworm Laboratory, Department of Zoology, D.D.U. Gorakhpur University, Gorakhpur 273 009, U.P., India

ABSTRACT: Variation in temperature significantly influenced the total protein content of silk gland in *Bombyx mori*. Maximum level of total protein (9.11 μg/mg) was noticed at 26 °C and minimum (5.56 μg/mg) at 10 °C. The protein content declined at higher temperature also.

KEYWORDS: protein, silk gland, *Bombyx mori*, temperature

Bombyx mori Nistari is a resistant variety of multivoltine mulberry silkworm in the northern belt of India which has been extensively studied by a number of workers. Silkworms are often exposed to a wide range of temperature variation which may cause changes in the biochemical factors like lipid profile (Hoffman, 1984). The effect of temperature has been noticed to influence the various life activities in silkworm. Thus, it is hypothesised that the variation in temperature may influence the protein level in silk gland of *B. mori* which is likely to have influence on the quantity and quality of silk.

The seed cocoons of multivoltine mulberry silkworm (*Bombyx mori)* obtained from the silkworm grainage Behraiech, Directorate of Sericulture, were maintained in plywood trays at 26 ± 1 °C and 80 ± 5% RH till the emergence of moths. The grainage operation was done as described by Krishnaswami *et al.* (1973). To observe the effect of temperature on the protein content in silk gland of B. larvae, the larvae were maintained in BOD incubator at temperature regimes of 10, 14, 18, 26, 34 and 38 °C. Each treatment was replicated six times. The silk glands of five day old fifth instar larva were collected from each replicate and the silk gland were dissected out. Estimation of total protein content in the silk glands was made following the method of Lowry *et al.* (1951) modified by Singh and Agrawal (1989). The data were analysed statistically by one way ANOVA.

*Corresponding author

TABLE 1. Effect of temperature on the total protein content (μg/mg) in the silk gland of *Bombyx mori* larvae

Temperature (°C)						F-ratio $n1 = 5$
10	14	18	26	34	38	
5.56 ±.060	6.22 ±.063	6.83 ±.080	9.11 ±.113	7.47 ±.111	-[a]	425.38*

[a] Not survived
The values represent mean and S.D. of six replicates.
* $P < 0.01$

The data (Table 1) indicate that the total protein content in the silk gland was considerably influenced by the temperature. Highest level of protein (9.11 μg/mg) was obtained at 26 °C. But further increase in temperature to 34 °C caused decrease in the total protein of silk gland to the level of 7.47 μg/mg. At 38 °C larvae did not survive after 3rd moult.

The total protein content present in the silk gland of *B. mori* declined notably with increasing cold treatment of silkworm eggs (Pandey and Upadhyay, 2002) but the pre-refrigeration period had no significant impact on the total protein level in the silk gland of *B. mori*. Variation in temperature significantly influenced the total free amino acid content of silk gland in *B. mori* (Gupta *et al.*, 2005). It may be concluded that with the increasing temperature, the rate of protein synthesis in the silk gland increased but at very high temperature range (34 °C), it declined sharply.

REFERENCES

Krishnaswami, S., Narasimhanna, M. N., Suryanarayan, S. K. and Kumar Raja, S. (1973) Sericulture Manual: Silkworm Rearing. *F.A.O. Agric., Services Bull. Rome* 15: 1–131.

Singh, D. K. and Agrawal, R. A. (1989) Toxicity of piperonyl butoxide carboryl synergism on the snail *Lymnaea accuminata*. *International Review der Gesamtem Hydrobiol* 74: 689–699.

Lowry, O. H., Rosebrough, N. J., Furr, A. L. and Randall, R. J. (1951) In: *Methods in Enzymology*, Colowick, S. P. and Kaplan, N. (Eds). Vol. III: 44–450.

Pandey, A. K. and Upadhyay, V. B. (2002) Influence of refrigeration of eggs and prerefrigeration period on the total protein content in silk gland of multivoltine mulberry silkworm *B. mori* L. *J. Ecophysiol. Occup. Hlth.* 2: 89–6.

Hoffman, K. M. (1984) Metabolic and enzymatic adaptation to temperature. In: *Environmental Physiology and Biochemistry of Insects*. Hoffman, K. M. (Ed). Springer, Berlin.

Gupta, S. K., Gaur, K. P. and Upadhyay, V. B. (2005) Influence of temperature on the total free amino acids content in the silk gland of multivoltine mulberry silkworm, *Bombyx mari* Line. *J. Ecophysiol. Occup. Hlth.* 5: 127–130.

(Received 16 September 2006; accepted 30 September 2008)

ENTOMON 33(4): 285–288 (2008)
Short Communication No. ent.33411

Record of a new gregarine parasite (*Xipocephalus* sp.) of the dragonfly, *Diplacodes trivialis* (Rambur)

A. Anitha Rani and V. Mahalingam*

G. S. Gill Researach Institute, Guru Nanak College, Chennai 600 042, India
Email: maligowri@hotmail.com

ABSTRACT: A new species of the gregarine protozoan belonging to the genus *Xiphocephalus* was recorded parasitizing the adults of the dragonfly, *Diplacodes trivialis* (Rambur) collected from the scrub jungle ecosystem. The uniqueness of the species is with the epimerite that is in the form of an elongated deltoid process with a bulbous terminal end.

KEYWORDS: Gregarine protozoan, *Diplacodes trivialis*, scrub jungle, epimerite, *Xiphocephalus*, dragonfly

Gregarines are an enigmatic group of intestinal protozoan parasite infesting arthropods (Lipa, 1967). They are cosmopolitan in distribution and considered as primitive eukaryotes (Clopton, 1997). Among the insects they parasitize the coleopterans, orthopterans and odonates (Baudion, 1961; Clopton, 1995; Johny *et al.*, 2000) are common. Study of this group of parasites has gained importance because of their potential as biocontrol agents of insect pests (Muralirangan *et al.*, 2000). Odonates are an ancient group of elegant insect enjoying worldwide distribution. They form an important component of the food chain. Their naiads as well as the adults play an important role in mosquito control. In view of this ecological importance *Diplacodes trivialis* (Rambur) (Anisoptera: Odonata) a common odonate inhabiting the scrub jungle ecosystem of Madras Christian College campus was screened for parasitization by gregarines. A total of 140 adults were examined and eight were found infected with the gamonts and trophozoites of *Xiphocephalus* sp. Having an epimerite elongated into a xiphoid process that terminates in a sharp or rounded structure (Theodorides, 1967) the characteristic feature of the genus *Xiphocephalus* two species of *Xiphocephalus* namely *X. gladiator* and *X. ellisi* have so far been described. The present species differs from the two described species in having a bulbous terminal deltoid process (Figures 1). *X. gladiator* has a long xiphoid and lanceolate epimerite whereas in *X. ellisi* the epimerite is elongate, xiphioid, and terminally obtuse with transverse basal tumidus. In the species under study (Figures 1, 2) the protomerite is broadly

*Corresponding author

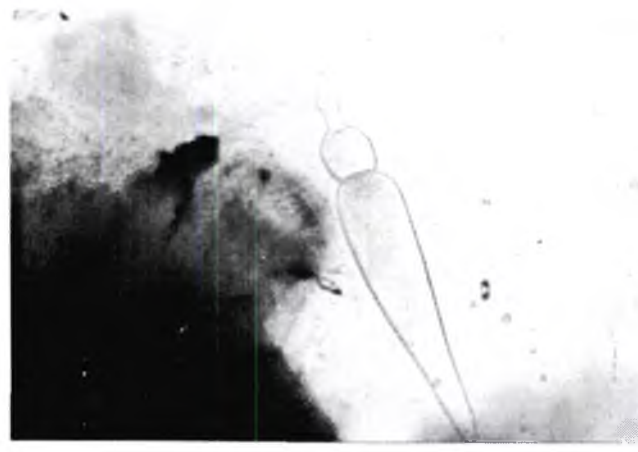


FIGURE 1. Tropozoite of *Xipocephalus* sp. (500x).

TABLE 1. Morphometric measurements of the gregarine *Xipocephalus* sp.

Parameter	Range	Mean	SD	SE	Coefficient of variance
TL	1204–2021.6	1619.18	41.2834	9.2313	2.549
LE	28–450	315.20	86.2271	19.2797	27.373
LP	182–329	246.55	43.9311	9.8233	17.888
LD	912–1290	1043.75	127.4836	28.5064	12.213
WE	28–84	62.90	14.5598	3.2556	23.147
WP	70–217	124.60	43.8386	9.8027	35.184
WD	91–245	169.05	39.9611	8.9356	23.638

TL, Total length; LE, Length of Epimerite; LP, Length of Protomerite; LD, Length of Deutomerite; WE, Width of Epimerite; WP, Width of Protomerite; WD, Width of Deutomerite.

ovoid and the deutomerite septum is clearly marked and constricted. The deutomerite is narrowly obovoid. Protomerite length (LP) of *X. ellisi* is 60.3–118.6 (84.1 ± 15.0), width (WP) is 85.3–168.7 (114.9 ± 21.2), deutomerite length (LD) is 150.6–1638.3 (1094.0±313.4) and total length (TL) is 737.4–1756.8 (1204±272.80). Morphometry of the species under study (Table 1) shows the LP is 182–329 (246.55 ± 43.93), WP is 70-217 (124.6 ± 43.83), LD is 912–1290 (1043.75 ± 127.43), TL is 1204–2021.6 (1619.18 ± 41.28). Differences in these structures indicate that the gregarine under study is a new species.

Odonaticola diplacodi and *odonatinola longicollara* infestation in *Diplacodes trivialis* was recorded by Kori and Amoji (1986) and Sarkar and Halder (1981). Biswas *et al.* (2004) recorded three new species of gregarines from dragonflies of West Bengal. Prasadan and Janardanan (1994) observed a new species of actinocephalid gregarine from the dragonflies of Kerala. Clopton (1997) stated that 200 gregarine species from

FIGURE 2. Gamont of *Xipocephalus* sp. (210x).

12 families have been discovered from Sandhills of Western Nebraska, U.S.A. The present study showed that 5.7% *Diplacodes trivialis* populations alone was parasitized. The low incidence level indicates that the gregarines may not pose a threat to the species under study.

REFERENCES

Baudion, J. (1961) Contribution a l'etude des gre'garines des dyctiscides (Insecta: Coleoptera. *Bulletin biologique de la france et de la delgique* 95: 389–404.

Biswas, S., Chatterjee, M. and Halder, D. P. (2004) New species of *odonoticola sarkar et Halder* (Apicomplexa: Conoidasida) from dragonflies (Insecta: Odonata) in West Bengal, India. *Act Protozool* 43: 183–191.

Clopton, R. E. (1995) *Domadracunculus jonoviji* n.gen., n.sp. (Apicomplexa: Actinocepalidae) is described from trophozoites, gamonts and oocysts collected from adult *Ischnura verticalis* (Odonata: Zygoptera) in Brazos country, Texas. *J. Parasitol.* 81(2): 256–259.

Clopton, R. E. (1997) *Grergarine Protocol Manual Hotel Intestine*, Laboratory of Parasitology, p. 5.

Johny, S., Muralirangan, M. C. and Sanjayan, K. P. (2000) Parasitization potential of two Cephalogregarine, *Leidyana subramanii* Pushkala and Muralirangan and *Retractocephalus dhauanii* sp. nov. on the Tobacco grasshopper *Atractomorpha cernulata* (fab). *Journal of Orthoptera Research* 9: 67–70.

Kori, S. S. and Amoji, S. D. (1986) On an Actinocephalid gregarine (Apicomplexa:Sporozoea) *Odonaticola diplacodi* sp. nov., from odonate insects, *Diplacodes trivialis* (Rambur). *Arch Protistenk* 131: 156–169.

Lipa, J. J. (1967) Studies on gregarines (Gregarinomoropha) of arthropods in Poland. *Acta Protozoologica* 67: 179.

Muralirangan, M. C., Sanjayan, K. P. and Johny, S. (2000) *Augmentation of Native Gregarine Parasite for the Management of Grasshopper of Agro Ecosystem*, 208–205.

Prasadan, P. K. and Janardaran, K. P. (1994) On a new species of Actonocephalid gregarine (Apicomplexa: Cephaline) from the dragonfly *Neurothermis fluvia* (Dury) of Kerala (India). *Fraseria* 1(1): 7–10.

Sarkar, N. K. and Halder, D. P. (1981) Observed on a new Cephaline gregarine (Protozoa: Sporozoa) *Acanthospora bengalensis* n.sp., from odonate insect. *Arch Protistenk* 124: 278–284.

Theodorides, J., Desportes, I. and Jolivet, P. (1964) Gregarines parasites de coleopteres dEthiopie. *Ann. Parasitol. Hum. Comp.* 39: 1–31.

(Received 10 August 2006; accepted 30 September 2008)

ENTOMON gratefully acknowledges the following reviewers, who offered their valuable time and expertise in evaluating the manuscripts during the year 2008

1. Dr. DUNSTON P. AMBROSE, Palayamkottai
2. Dr. K.P. GOPINATHAN, Bangalore
3. Dr. K.M. KHURAD, Nagpur
4. Dr. G. MADHAVAN NAIR, Trivandrum
5. Dr. MARIAMMA JACOB, Trivandrum
6. Dr. N. MOHANDAS, Trivandrum
7. Dr. H. NAGARAJA, Bangalore
8. Dr. K.S.S. NAIR, Trivandrum
9. Dr. K.D. PRATHAPAN, Trivandrum
10. Dr. R. RAJENDRAN, Alappuzha
11. Dr. S.B. SUBY, Gwalior
12. Dr. R. SUNDERARAJ, Bangalore

GUIDELINES TO AUTHORS

Scope: ENTOMON will publish original research papers on insects, arachnids and myriapods. Reviews are not acceptable.

Papers on morphology, anatomy and histology will be considered only when they form part of systematics, physiology or behavioural studies.

Announcements of seminars/symposia, book reviews and other items of entomological interest will also be considered for publication.

Types of papers: Articles up to 3 printed pages in length (1800 words) will be published as **short communications** and those between 4 and 10 pages (up to 6000 words) as **full papers**.

Full paper should be organized under the following sub-heads—Abstract, Introduction, Materials and Methods, Results, Discussion, Acknowledgements and References.

Short communication should be organized in the same way, but without the subheadings.

Publication policy: Manuscripts submitted for publication in ENTOMON should not have been published or submitted for publication elsewhere.

At least one of the authors should be a member of AAE.

Page charges are applicable at the rate of Rs. 100 per printed page for authors in India and US $ 10 for authors overseas. Invoice will be sent to the authors along with the galley proof.

Twenty five **reprints** of the paper will be supplied free of cost to the authors.

Typing and submission: Manuscripts should be typed double space on one side of good quality paper, having 3.5 cm left margin and 2.5 cm right margin.

The first page should contain the title, author's name affiliation and e-mail address. When the number of authors is more than one, indicate the name of the corresponding author with an asterisk and specify 'Corresponding author' in a footnote. The second page should contain the abstract, followed by key words and a running title. From page 3 onwards, type the text continuously from Introduction to References. Place the tables on separate sheets at the end of the paper. The pages should be numbered.

Three copies of the manuscript, complete in all respects including illustrations, should be sent to the Managing Editor, ENTOMON, Department of Zoology, University of Kerala, Kariavattom P.O., Thiruvananthapuram 695 581, Kerala, India.

An electronic version need be sent only after acceptance of the paper for publication.

Guide for writing: Careful attention to the following guide will facilitate early acceptance of your paper for publication in ENTOMON. Although some of these suggestions may appear trivial, they have been prompted by our experience in reviewing the papers received for publication. Keep in mind that ENTOMON is a research journal and your paper will be read only by those who are specialists in the respective fields of research.

Title should be brief and should reflect the specific content of the research reported in the paper.

Abstract should be informative, not indicative. It should very briefly highlight the aim of the study and major conclusions. Normally it should not exceed 150 words.

Key words should be limited to four or five most pertinent indicators of the work, relevant to indexing the article.

Introduction should be brief, normally not exceeding 300 words. Include the specific aim of the research, a review of the available information in the area and existing gap in knowledge. The introduction should thus justify the work carried out. Avoid elementary details and repetition of well known facts. For example, in a paper reporting the efficacy of a biopesticide against a particular pest, it is not necessary to explain the hazards of chemical pesticides, alternative methods of insect control and advantage of integrated pest management. Limit the literature review to what is most relevant to the topic under study.

Materials and Methods should provide just enough details to permit proper interpretation of the results. Materials used need not be described separately if it is evident from the methods given. Technical description of the method is needed only when the method is new. If the method followed has been already described elsewhere, just give the reference. If any alteration is made, describe the alteration alone, with reason.

Results: Adequate care should be taken to organize and present the results in a clear, concise and summarized form.

Quantitative data should always be analysed using suitable statistical methods. Organize the data into well planned tables. Each table should be self-explanatory.

Do not repeat the data presented in the table in the text. Quote the relevant figures in the text only when it is essential for highlighting some particular finding.

Due care should be taken while interpreting the results of statistical analysis. For example, treatments which show higher numerical value cannot be treated as superior to those having lower numerical values when there is no statistically significant difference.

Interpretation of the data should be with reference to the objectives set in the experiment.

Do not include graphs duplicating the data presented in the tables.

When the research involves repetition of the work already reported by others, include the new findings alone in the paper.

Illustrations included in the paper should be essential for explaining some points in the text. Photographs of the life stages of an insect are not useful unless the insect is being reported for the first time. Illustration should be of good quality. Limit the number of photographs to 4–6 and organize them into plates wherever possible. The illustrations should be numbered consecutively as Fig. 1, Fig. 2, etc., without distinction between drawings, graphs and photographs. Labelling should be legible and large enough to stand suitable reduction. Legend for the figures should be typed on a separate page. All figures must be referred to, at appropriate places, in the text.

The cost of printing colour illustration is to be met by the author.

Discussion: The discussion section is intended to critically analyse and interpret the results with reference to the objectives set forth in the study. It should highlight the importance of the results in relation to what is already known. It should also point out the limitations of the study, if any. The discussion should not repeat details given under Results, except to highlight some conclusions.

References should list all publications cited in the text, in alphabetical order. Do not include any references not cited in the text. Some authors show a tendency to cite too many references in support of a statement. Cite only a few references most pertinent to the point dealt with. Follow the citation style given below.

Examples of citations in text:

Krishnaswamy (1978, 1979)

Govindan *et al.*(1998)

(Reddy 1978; David 1991)

Examples of citations under References:

Articles in Journals:

Nayar K. K. (1953) Neurosecretion in *Iphita*. Current Science 22(2): 149.

Nair M. R. G. K. and Mohandas N. (1962) On the biology and control of *Carvalhoeia arecae*, a pest of areca palms in Kerala. Indian Journal of Entomology 24: (1) 86–93.

Jalaja M., Muraleedharan D. and Prabhu V. K. K. (1973) Effect of extirpation of median neurosecretory cells on reproduction in the female red cotton bug, *Dysdercus cingulatus*. Journal of Insect Physiology 19(1): 29–36.

Books and Articles in Books:

Novak V. J. A. (1966) *Insect Hormones*. Methuen and Co., 478 pp.

Wigglesworth V. B. (1964) The hormonal regulation of growth and reproduction in insects. In: *Advances in Insect Physiology* Vol. 2 (Eds. Beament J. W. L., Treherne J. E. and Wigglesworth V. B), Academic Press, London, pp 247–335.

Review Procedure: Manuscripts will be subjected to a preliminary scrutiny by an Editorial team and those conforming to the general guidelines set above will be referred to experts for detailed review; others will be returned to the author for resubmission in the prescribed format. Based on detailed review, the corresponding author will be advised of acceptance, non-acceptance or need for revision. The revised

manuscript will be scrutinized again by an Editorial team (and by expert referees, if needed) before final acceptance. On final acceptance, the author will be asked to submit an electronic version of the manuscript. Proof will be sent to the corresponding author. It should be checked and returned within three days of receipt. The journal reserves the right to proceed with publication if corrections are not communicated promptly.

Strict conformity with the above guidelines will ensure speedy publication of your paper.

Contents of Volume 33

No. 1

No. 2

No. 3

SHORT COMMUNICATIONS

No. 4

SHORT COMMUNICATIONS

AUTHOR INDEX

Reg. No. 123SBN

Edited, printed and published by D. Muraleedharan for and on behalf of Association for Advancement of Entomology, CABB, University of Kerala, Trivandrum. Typeset in TEX by River Valley Technologies, Trivandrum. Printed at St. Joseph's Press, Trivandrum

ISSN 0377–9335

Vol. 33 December 2008 No. 4

CONTENTS

Centre for Arthropod Bioresources and Biotechnology (CABB),
University of Kerala, Kariavattom, Trivandrum, India 695 581